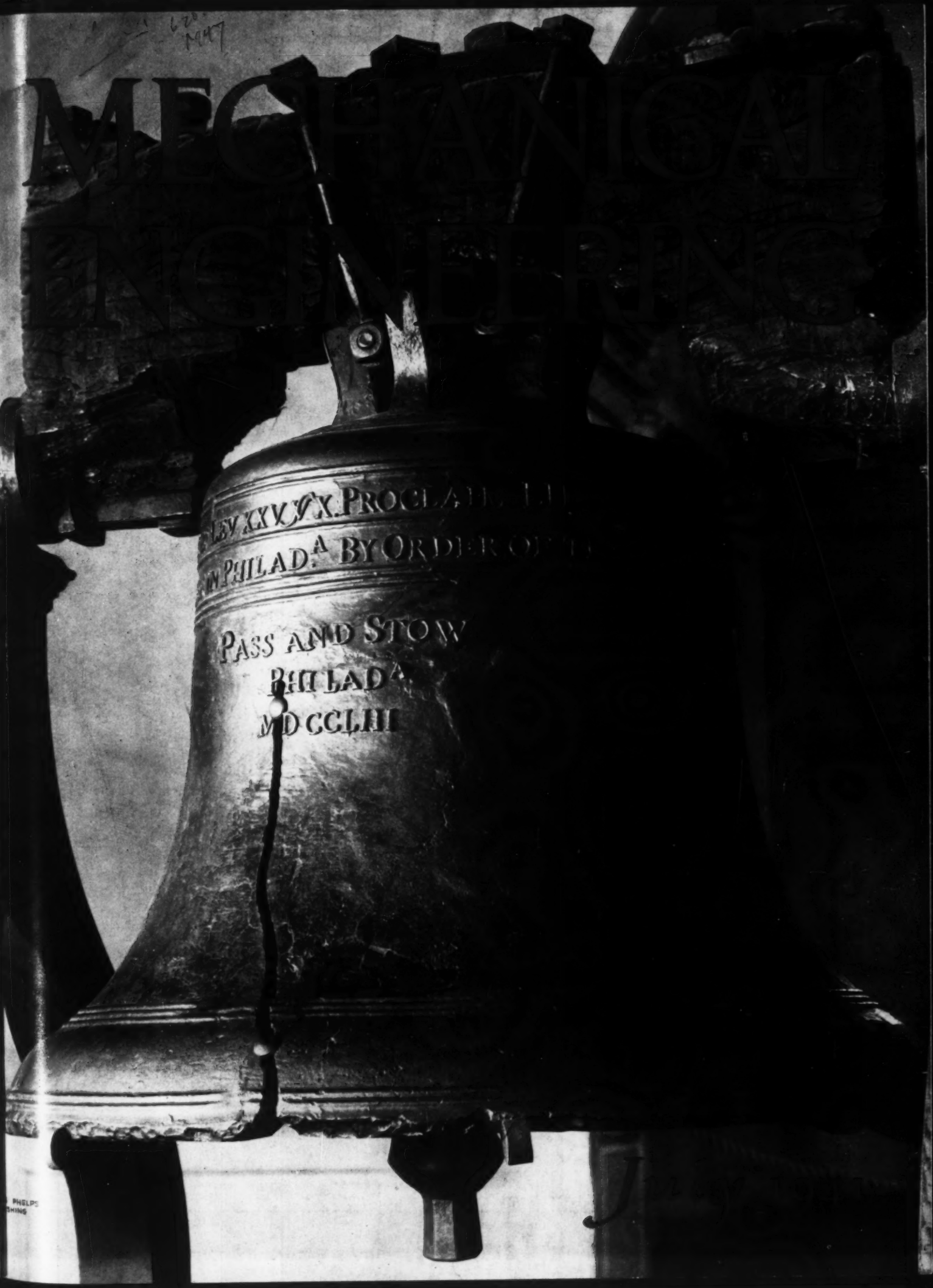
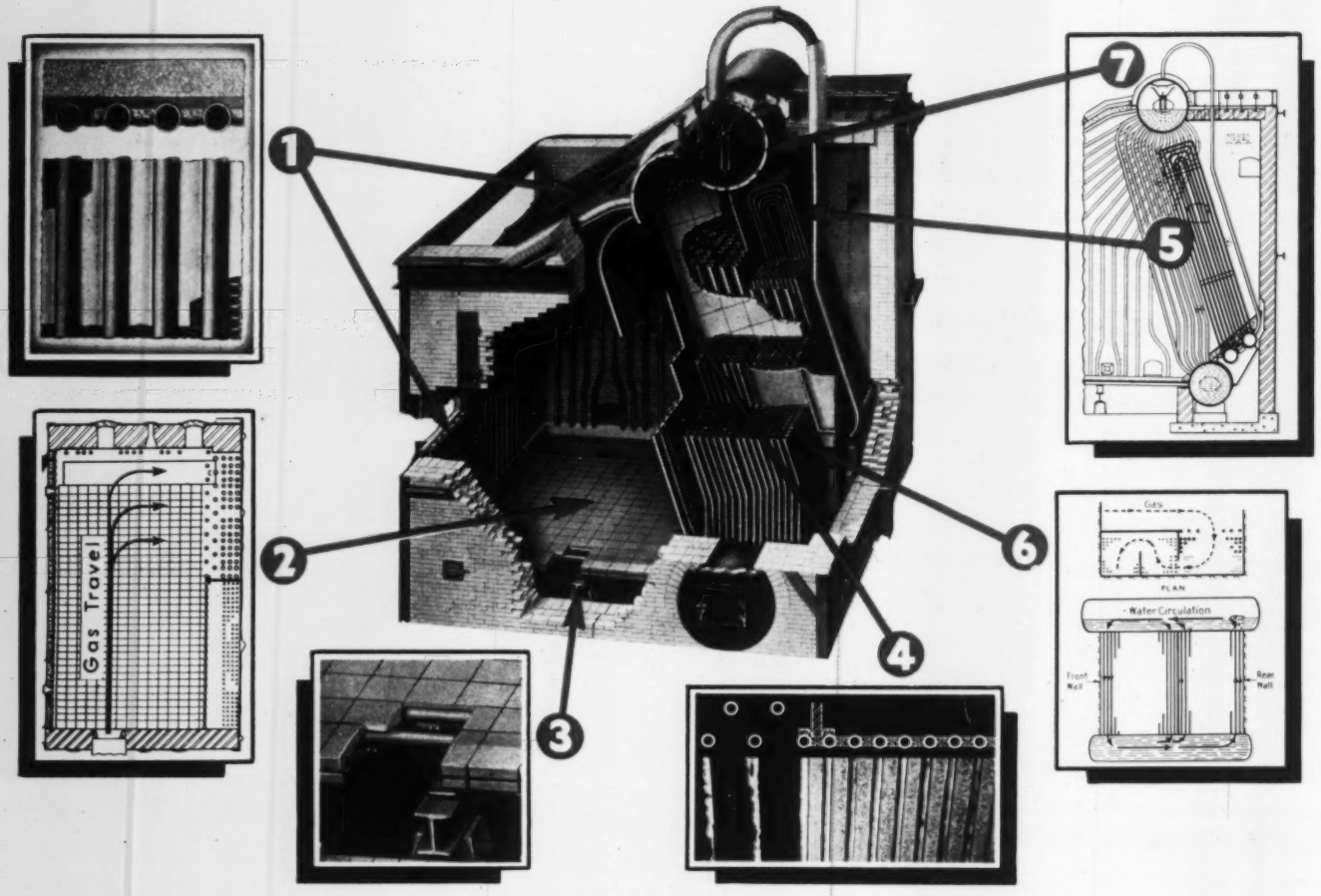

MECHANICAL
ENGINEERING
LEV XXV.V X. PROCLAIM
IN PHILAD.A BY ORDER OF
PASS AND STOW
PHILAD.A
MDCCLIII

For Dependable Economical Service- *the* **INTEGRAL-FURNACE BOILER**



The B&W Integral-Furnace Boiler provides such dependable and economical service that a large number of the 350 now in operation have been installed on repeat orders. Many single-unit installations are successfully carrying entire plant loads. Some of the outstanding design features that contribute to its recognized high availability for service are listed below.

1. The water-cooled furnace sidewalls and roof are of the same durable stud-tube construction that is used in large central-station boilers.
2. The deep furnace, fired from one end, provides ample space for complete combustion with minimized surface fouling, resulting in high rates of radiant absorption by the wall surfaces.
3. The bare metal blocks, which cover and protect the tubes of the water-cooled furnace floor, provide a surface readily cleared of ash.
4. A slag screen shields the first bank of boiler tubes from direct furnace radiation, and a stud-tube wall shields the second and third banks.
5. The self-draining superheater design prevents any accumulation of water in the tubes, and assures steam flow through all tubes on starting up.
6. The tubes of the third bank, which is in the zone of coolest gases, act as downcomers, insuring rapid positive circulation at all loads.
7. All furnace and boiler tubes enter the upper drum *below the normal water-level*, and, being full of water, cannot be overheated during start-up.

Full particulars of the Integral-Furnace Boiler are contained in Bulletin G-17-A — copy on request.

THE BABCOCK & WILCOX COMPANY **85 LIBERTY STREET, NEW YORK, N. Y.**

BABCOCK & WILCOX

G-199

MECHANICAL ENGINEERING

Published by The American Society of Mechanical Engineers

VOLUME 63 NUMBER 7

Contents for July, 1941

DEVELOPMENTS IN CONTINUOUS ANNEALING OF STEEL STRIP	*J. D. Keller*	507
SUBCONTRACTING PROBLEMS	*L. B. Coon*	514
ADMINISTRATIVE ORGANIZATION FOR A SMALL MANUFACTURING FIRM	*Willis Rabbe*	517
SAFETY FEATURES ON MILLS AND CALENDERS FOR RUBBER AND PLASTICS	*J. Milward*	521
THE ENGINEER'S RESPONSIBILITY IN MANAGEMENT	*T. H. Ross*	524
THE FORGE OF VULCAN	*J. W. Higgins*	527
THE PRESSED-STEEL INDUSTRY	*C. C. Higgins*	534
THE CHROME-HARDENING OF CYLINDER BORES	*H. Van der Horst*	536
LABOR UNDER THE DEFENSE PROGRAM	*C. A. Myers*	540

EDITORIAL	505	A.S.M.E. BOILER CODE	556
BRIEFING THE RECORD	543	REVIEWS OF BOOKS	558
COMMENTS ON PAPERS	549	A.S.M.E. NEWS	560

INDEX TO ADVERTISERS 52

OFFICERS OF THE SOCIETY:

WILLIAM A. HANLEY, *President*

W. D. ENNIS, *Treasurer* C. E. DAVIES, *Secretary*

PUBLICATION STAFF:

GEORGE A. STETSON, *Editor* FREDERICK LASK, *Advertising Mgr.*

COMMITTEE ON PUBLICATIONS:

C. B. PECK, *Chairman*

F. L. BRADLEY A. R. STEVENSON, JR.

C. R. SODERBERG E. J. KATES

ADVISORY MEMBERS OF THE COMMITTEE ON PUBLICATIONS:

W. L. DUDLEY, SEATTLE, WASH. N. C. EBAUGH, GAINESVILLE, FLA. O. B. SCHIER, 2ND, NEW YORK, N. Y.

Junior Members: C. C. KIRBY, NEW YORK, N. Y., AND F. H. FOWLER, JR., CALDWELL, N. J.

Published monthly by The American Society of Mechanical Engineers. Publication office at 20th and Northampton Streets, Easton, Pa. Editorial and Advertising departments at the headquarters of the Society, 29 West Thirty-Ninth Street, New York, N. Y. Cable address, "Dynamic," New York. Price 60 cents a copy, $5.00 a year; to members and affiliates, 50 cents a copy, $4.00 a year. Postage outside of the United States of America, $1.50 additional. Changes of address must be received at Society headquarters two weeks before they are to be effective on the mailing list. Please send old as well as new address. . . . By-Law: The Society shall not be responsible for statements or opinions advanced in papers or . . . printed in its publications (B13, Par. 4). . . . Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879. . . . Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921. . . . Copyrighted, 1941, by The American Society of Mechanical Engineers. Member of the Audit Bureau of Circulations. Reprints from this publication may be made on condition that full credit be given MECHANICAL ENGINEERING and the author, and that date of publication be stated.

Galloway, N. Y.

Men and Machines Against Time

(In machine shop at gear hobber working on motor gear for rotary pump.)

VOLUME 63
No. 7

MECHANICAL ENGINEERING

JULY
1941

GEORGE A. STETSON, *Editor*

Substitute Materials

IN THE A.S.M.E. News Section of the current issue appears a notice published at the request of the Wood Finishing Committee of the Wood Industries Division of The American Society of Mechanical Engineers which directs attention to the need for thinking about substitute materials and methods of wood finishes.

Possibly because to the man on the street shortages of materials in the particular field of interest of the Wood Industries Division are not obvious in view of all the public attention being directed to aluminum and other metals, the notice serves sharply to emphasize some of the far-reaching effects of the war upon our peacetime habits. As time goes on the number of industries that will feel the pinch of emergency times will increase. Engineers particularly will find it necessary to give an increasing amount of thought to speeding up production of materials that are in demand but becoming scarce, to finding and developing new sources of supply when such are available, to discovering substitute materials which may be just as satisfactory or can be made so, and to devising new materials based upon raw stocks of which there is an abundance or to changing designs or methods which do not call for substances hard to get.

The challenge of necessity will undoubtedly be met in a way that will surprise us and provide in commercial quantities new materials now in the research stage. The alternative of hoarding stocks that may become scarce is a stop gap that will appeal more to the commercial man than to the engineer. The engineer will also have his attention riveted on the stoppage of waste and the salvage of scrap. All in all there will be abundant opportunity for the engineer to use the common sense and ingenuity for which he is noted.

One other comment is appropriate. The situation calls for a free interchange of information on materials, on successful substitution of materials, on methods, and on waste elimination. In this field engineering societies and publications can be of service if those who have information to share will share it.

Engineers Face the Future

IN A critical emergency it is difficult to concentrate on what to do when the emergency is over. Yet if we are to avoid a continuous appearance of emergencies we had better make up our minds to face the next one before it is upon us. This was the burden of Past-President Batt's message to The American Society of Mechanical Engineers at its 1940 Annual Dinner, and has been the theme of addresses and articles by other forward-looking men who have lived through one war and its subsequent economic and social consequences. Somebody should be thinking about the next step and making plans to avoid as much as possible the customary havoc that follows war. And if somebody, why not everybody?

Postwar problems will fall into three interdependent categories—political, social, and economic. It is trite to say that the outcome of the war will set the stage upon which the attack on these problems will take place. The outcome of the war and the terms of the return to peace will determine the nature and relative intensity of the problems and provide the broad pattern of the solutions. Although we can speculate in general terms on these problems, we cannot formulate them accurately today. Hence the temptation is to avoid thinking about them; but an encouraging feature of the times is the fact that many persons are thinking about them and organizing groups to study plans for future action. This awareness is a healthy sign if it does not lead to a too early crystallization of ideas and programs that may prove valueless or inappropriate when the time for action arrives. Another danger in the present situation lies in the possibility that the wrong groups may be making the plans for the future, so that, when postwar problems are actually present-day problems, wrong solutions will be adopted. Our best groups need to exercise a nimbleness of intelligence that will avoid inability to adapt their programs to changing conditions and a bankruptcy of ideas and energy to put them into practice.

One need not stick his neck out very far to state that a period of destruction will be followed by one of reconstruction; that intensive use of facilities foreshadows a task of deferred maintenance; that conversion of wartime to peacetime production will have to be faced; or that it will be difficult to provide for continuity of employment for everyone engaged in wartime work. One would be more cautious in predicting what effect a two-ocean navy will have; how national defense against future troubles, universal service, international law and order, development of retarded communities, and access to markets and raw materials, to name a few elements, will change the pattern of our lives; or what economic competition with other nations, the balance of relationships between capital and labor, governmental regulation of private enterprise, social security, and distribution of wealth on the one hand and intensive research, education, unity of purpose, and the revitalization of our institutions on the other will do to us.

The point is that although we cannot see the specific

problems of some years hence, we can be intelligently conscious of trends and keep ourselves alert to grapple with acute cases as they arise. To a surprising degree engineers are caught up in the forward surge of these trends in a manner that affords them opportunity to observe and in a measure at least to influence them. Should they not, therefore, organize a group or many groups to give thought to these matters and to be ready, to cooperate with others when need arises?

Engineers resented the popular condemnation, frequently heard during the depression of the thirties, that they were largely responsible for the economic failure of society to function smoothly. Engineering will be bankrupt indeed if it fails to head off, by intelligent and intensive concern with national and world affairs, a similar condemnation if postwar conditions become unbearable.

Engineers are no more than human. Like other human beings they can be overwhelmed by forces too powerful to control. But they have intelligence, energy, and a knowledge of how to get things done. If they can combine these gifts with understanding and leadership, who can predict what services they may perform in the cause of recovery from today's madness?

A.S.M.E. Members on the Job

AS succeeding issues of this magazine afford space for papers relating to mechanical engineers and defense work and as the A.S.M.E. News Section records Society activities in this field, the extent of A.S.M.E. contribution becomes impressive. Speaking at Philadelphia in May, Secretary Davies said in this connection:

> As a national body your Society is doing its best in the defense effort. It is significant that five of its past presidents are on duty in Washington in positions of high responsibility in production, construction, and research. Your Committee on National Defense has functioned successfully and has quietly contributed to bring the engineering skill of the country into closer touch with the many defense agencies. Meetings and publications, the traditional services of an engineering society, have been largely focused on defense activities. Since October, ninety meetings have been devoted to defense subjects. Your president, who has consecrated his efforts to arousing the Society to the need for "all-out" effort, has made twenty-three addresses. Some thirty papers, recording experience in defense production, are or will be published for the benefit of others who are faced with similar problems. Your Secretary has been made available for defense work.

Opportunities for service on the part of A.S.M.E. members are increasing day by day. The knowledge and experience of mechanical engineers fit them for an unusual number of tasks on behalf of the national welfare. Individually and in groups of committees they can make available their services in the settlement of labor disputes. They can spread the practice of subcontracting until the production effort on behalf of national defense includes every shop and production facility in the land. They can and will throw their energies and talents into the programs of civilian defense that are being organized in many communities. And until demands for these special services are made on them they can apply themselves to their normal occupations with diligence and industry, maintaining themselves in a condition of physical and mental fitness for the sacrifices and more intensive efforts that are bound to come. In the meantime they do not need to wait for special calls. In local sections and in their home communities they can study the needs of the situation and organize themselves into groups for appropriate action.

Arts of War and Peace

LOOKING back with Mr. Higgins over 6000 years of the history of the working of metals, one is constantly impressed with the intermingling of the arts of war and peace, and of the manner in which the manufacture of munitions has developed skills and products of a civilizing nature. Viewed in the light of this long history, mass production and functional design appear to have an extremely remote origin and the dependence of success of arms upon the implements of war and the skill of the artificer to be no recent thing.

In the minds of the armorers, as in the minds of the warriors, were three essentials to superiority— mobility, protection, and striking power. To permit the fighter and his mount to move quickly, to protect against both blows and cuts, and to place in his hand a weapon that would pierce the armor of his opponent—these objectives were constantly sought.

Today, as in the days before the machine and the firearm, it is the skill of the designer and the manufacturer that provides the superior weapons. There is the race for better armor, for higher speed, and for greater striking power in which thousands of men apply their knowledge and skill and the fruits of their researches. Fortunately, it is not all lost in war's destruction. The arts of war await only the change of men's purposes to become the arts of peace.

Heat Transfer Grows

FOR a group that has only recently attained an autonomous status, the A.S.M.E. Heat Transfer Division can point to a large percentage of members who have expressed interest in its field of activity. Organized under the A.S.M.E. Process Industries as the Heat Transfer Group, the new division, from an actual count of members expressing interest in professional-division activities, shows that practically 18 per cent of A.S.M.E. members are concerned with heat transfer. To judge from the importance of the subject, the rapid growth of the literature in this field, and the extension of the number of problems that arise, particularly with the expansion of the chemical, petroleum, and process industries, to say nothing of power-plant apparatus always important to mechanical engineers, registration of members in the Heat Transfer Division is due to rise. In the meantime, the division's executive committee is doing an excellent job of securing papers in its field, thus providing needed information for engineers.

Developments in CONTINUOUS ANNEALING *of* STEEL STRIP

By J. D. KELLER

ASSOCIATED ENGINEERS, PITTSBURGH, PA.

IN the manufacture of steel sheets and strip, after the product has been reduced to the desired thickness by rolling, it must be annealed in order to reduce the hardness and increase the ductility, so that the material will be capable of being further processed, as by drawing or forming. In present practice, the material, either in the form of sheared sheets or in coils, is annealed in batches, in closed boxes filled with a gas atmosphere which is neutral or, more usually, somewhat reducing. A furnace of this type, called an "annealing cover," is shown in Fig. 1, and is suitable for either piled sheets

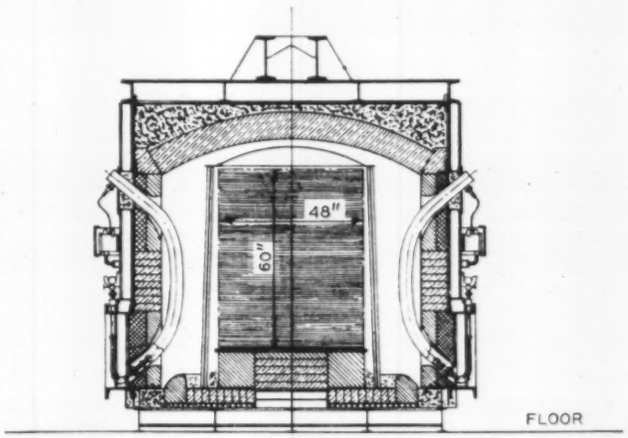


FIG. 1 TYPICAL "ANNEALING COVER" USED FOR PILED SHEETS OR COILS

or coils. In Fig. 2 is shown a unit designed especially for coils. For low-carbon steel, the material is heated to about 1300 F. The operation requires from 36 to 54 hours.

Within the last ten or twelve years, the manufacture of steel sheets and strip has been revolutionized, so that at present every operation in the chain of production is continuous, except annealing. The question naturally arises: Why is annealing the exception, and why is batch annealing still almost universally used, especially in view of the fact that continuous annealing has been successfully used for wire, and for nonferrous and alloy strip? The answer is that there were thought to be excellent metallurgical reasons why annealing could not be done continuously, and there were also no mean difficulties connected with handling the hot strip in the furnace. For these reasons, in spite of the very considerable cost of batch annealing and of its ancillary operations, this type of treatment was felt to be indispensable for producing the required characteristics in the finished material.

Recent trials of continuous furnaces have shown, however, that continuous annealing can produce strip material having characteristics equal to or superior to those of batch-annealed material for many uses; and means of overcoming the troubles in handling the hot strip have been worked out. If the development of continuous annealing of strip progresses as it bids fair to do, the last noncontinuous step in the series of operations in making strip steel will soon have been made continuous; resulting in a radical decrease in the cost of this operation, in increase of productive capacity, and in practically absolute uniformity of material produced.

Attempts to introduce continuous annealing have covered a considerable period. As far back as 1915, gas-fired "blue-annealing" furnaces were used through which the sheets were passed over rollers in the hearth. More recently a continuous furnace for normalizing auto-body sheets was installed at a Detroit plant, as described[1] by F. T. Hague and P. H. Brace. This furnace is over 300 ft long, is electrically heated, and operates at about 1750 F. Within the last two years, three other strictly continuous furnaces have been installed for handling strip in coils rather than separate sheets. One of these, installed in the Chicago district, is called a "catenary" furnace, because the strip is suspended under some tension between two rollers at either end of the horizontal furnace, forming a catenary curve; the furnace is gas-fired, using radiant tubes, but a protective atmosphere is not used, and it therefore

[1] "Annealing and Normalizing Auto-Body Steel in Electric Furnaces," by F. T. Hague and P. H. Brace, *Iron and Steel Engineer*, vol. 13, Sept., 1936, pp. 47–58.

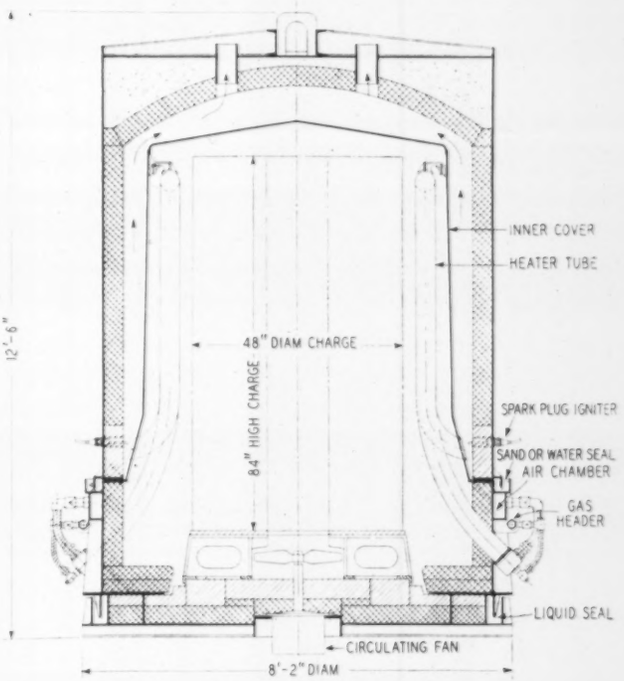


FIG. 2 ANNEALING UNIT DESIGNED FOR COILS

Presented at the Fourth National-Defense Meeting, Pittsburgh, Pa., May 2, 1941, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

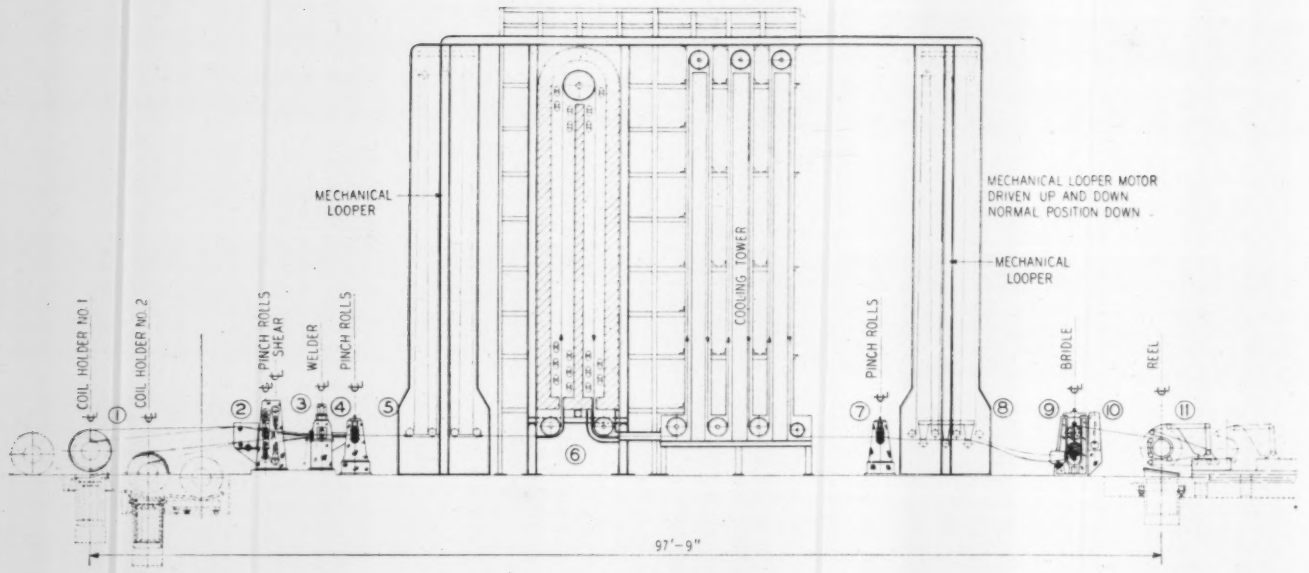


FIG. 3 GAS-FIRED TOWER-TYPE STRIP ANNEALER, INCLUDING HANDLING EQUIPMENT

acts as a blue-annealing rather than as a bright-annealing unit.

A second installation, in the Pittsburgh district, is understood to consist of a tower-type furnace about 60 ft high, electrically heated, through which the strip passes at a rather slow speed, somewhat over 50 fpm, being heated to about 1725 F, and then cooled to about 150 F, both in a protective-gas atmosphere. The purpose here, however, is not annealing, but treatment of a tin layer which has previously been formed on the surface.

A third installation, at the plant of a closure-and-container manufacturer in the Baltimore district, consists of two tower-type electrically heated furnaces about 30 ft high, each having a capacity of about three tons per hour, producing bright-annealed strip at a speed of about 200 fpm. More recently, this has been increased to 320 fpm, and men of experience state that speeds of 500 fpm and over are not impossible.

In Germany, the Rohn continuous furnaces are reported to be in use for bright annealing. They are electrically heated and are similar to the Baltimore furnaces just described.

Horizontal continuous furnaces must be long, if a reasonably high production rate is to be attained; in fact, the length may be prohibitive, with regard to the tension produced in the strip. Also, the surface of the strip appears likely to be damaged. On both of these counts, as well as on account of the smaller floor space required, the tower-type furnace is felt to be far preferable.

For those who are not familiar with strip-mill practice, it may be well to point out that box annealing in present-day practice is preceded by scrubbing or electrolytic cleaning of the strip, in order to remove the oil which is left on its surface and in fact pressed into its pores by the extreme pressure of the rolls in the cold-reduction mill through which it has passed. If the oil were left on the strip during box or pack annealing, it would cause localized discoloration of the surface, or would deposit a thin but adherent layer of carbon.

Following the box annealing, the strip must be "temper-passed" or "skin-passed," otherwise the dead soft material would crease or flute in subsequent operations or even in coiling and uncoiling; while in drawing and forming, "stretcher strains" or "snakes" (in reality Lüders' lines) would occur which disfigure the appearance of the surface. Temper passing requires a reduction of only about 5 per cent, but it necessitates an additional heavy and expensive mill. Hence, in comparing continuous annealing with present annealing practice, one must consider not only the cost of the operation of annealing in itself but also the cost of the preceding cleaning and the succeeding temper passing, both of which and especially the latter are very expensive operations, much more so than the annealing alone. This is one place in the modern semicontinuous process of making strip or sheets in which the costs are far greater than in the old-type tin-mill process.

On the basis of the successful results obtained with electrically heated tower-type furnaces, a design of gas-fired tower-type strip annealer has been evolved and is now being introduced in the steel industry; it is expected to produce even better results. A complete full-size unit or "line," including handling equipment, is illustrated in Fig. 3, while the furnace itself including the cooling chutes is shown in Fig. 4, to a larger scale. The equipment shown in these illustrations is designed to handle steel strip from 0.0086 to 0.025 in. in thickness, up to 38 in. wide, at speeds of 75 to 300 fpm. When handling the usual size, namely, strip 0.01 in. thick and 30 in. wide, at a line speed of 200 fpm, the output should be approximately 12,000 lb per hr. A gas-fired experimental unit of the same design but of smaller size is about to be installed at an Ohio steel plant.

FURNACE AND COOLING ZONE

The furnace, shown in Fig. 4, is a vertical furnace about 30 ft high, having two passes, heated by horizontal gas-fired radiant tubes on both sides of the strip. The tubes are of U or hairpin shape, and alternate tubes along the height are entered from opposite sides of the furnace, in order to give uniformity of temperature across the width of the strip. The furnace is designed to operate normally at a temperature of 1300 F, with a maximum operating temperature of 1700 F.

The strip on leaving the furnace passes through six vertical cooling chutes, in which its temperature is reduced to 200 F or lower. The gastight chutes are water-jacketed. In addition, the strip in passing through them is cooled by forced convection. Both the heating and the cooling are ordinarily effected with the strip immersed in a protective-gas atmosphere, in order to retain the bright surface of the strip.

Control of the temperature in the furnace is completely automatic, with nine control zones. Each zone has a potentiome-

ter-pyrometer controller of the proportioning type, which varies the gas through throttling-type valves in accordance with the heat input required for that zone of the furnace. For the first eight zones, the potentiometer controller is of the indicating type, while for the ninth zone it is of the recording type.

HANDLING EQUIPMENT

Fully as important for satisfactory results as the furnace itself is the rest of the "line," comprising the handling equipment shown in Fig. 3.

Coil Holders. The two coil holders (1), at the left in the illustration, are of the cone type, hydraulically operated. The coils of strip are delivered to No. 1 coil holder on a ramp, and raised by the hydraulic lift into position to be clamped by the cones. A coil carriage, as indicated in the illustration, is provided to permit entering a coil in the No. 2 coil holder while strip is being paid off from the No. 1 holder. Each coil holder is equipped with an adjustable friction brake for providing back tension.

Combination Shear-and-Pinch-Roll Unit. The double-acting shear (2) has a center knife-blade in fixed position and independently operated shear knives both below and above the center knife. The pinch rolls have a center idler roller and independently driven air-operated upper and lower rolls.

Seam Welder. For welding the front end of the incoming coil to the rear end of the coil which is passing through the furnace, an electrical contact seam welder (3) is arranged to make two parallel welds across the strip simultaneously at welding speeds of from 15 to 45 fpm. In addition, the device is arranged to permit making a series of intermittent or spot welds rather than a continuous seam weld. The intermittent weld eliminates the tendency of very thin material to buckle at the weld during annealing.

Pinch Rolls. Pinch rolls (4) at the entrance end serve to feed the strip to the mechanical looper preceding the furnace. The pinch rolls (7) following the cooling tower serve to govern the movement of the strip through the furnace and cooling tower. The two sets of pinch rolls together with the looper (5) maintain the correct tension in the strip while passing through the furnace and cooler.

Mechanical Looper. The purpose of the mechanical looper at the entry end (5) is to permit an accumulation of slack in the strip (at the same time maintaining uniform tension), so that, when the motion of the rear end of the coil is stopped in order to permit joining the strips in the welder, the movement of the rest of the strip through the furnace can continue uninterruptedly and at uniform speed.

The purpose of the similar looper (8) at the exit end is to take up the slack while the front end of the coil is stopped to permit cutting out the weld, and the rest of the coil is coming out of the furnace at constant speed.

Tension Bridle. The tension bridle (9) has the important function of maintaining sufficient back tension on the strip to permit the reel to wind a tight and uniform coil.

Upcut Shear. The fast-acting upcut shear (10) is used for cutting out the weld from the strip, again separating the coils which had been welded together for the purpose of permitting continuous drawing of the strip through the furnace.

Drum-Type Reel With Wrapper and Stripper. The reel (11) on which the strip is recoiled is of the collapsing-head type, driven from a separate variable-speed motor through a gear-reduction unit. For fast entry of the leading end of a strip on the reel, an automatic belt wrapper is provided, as shown by the broken lines at the extreme right in Fig. 3. This unit is brought into position by an air-operated cylinder, and is moved back after the coil is started, to be out of the way when stripping the coil.

A stripping device, consisting of a car running on rails and actuated by an air cylinder, is provided for removing coils from the reel. A hydraulically elevated platform is mounted on the car for supporting the coil during the stripping operation.

SEQUENCE OF OPERATIONS

Assuming that the line is in operation with the strip being paid off from the No. 2 coil holder, a coil is then entered on the No. 1 coil holder and the end of the strip is fed by hand to the combination unit (2), where an air cylinder is operated to clamp the strip between the upper and center pinch rolls. The leading end of the strip is then cropped by the upper shear blade, whereupon the upper pinch roll feeds the end of the strip up to the welder. Meanwhile the strip from No. 2 coil is passing at full speed through the open lower portion of the shear-and-pinch-roll unit.

When the end of the coil being paid off from the No. 2 coil holder is about to be reached, the operator speeds up the feeding pinch rolls (4). The counterweighted top rolls of the looper move upward, pulling the strip with them, and accumulating approximately 120 feet of strip in the looper when they have reached the top of the travel. When the tail end of the coil reaches the shear (2), the feeding pinch rolls (5) are operated to bring the end of the coil into welding position and hold it there, while it is being welded to the leading end of the strip from the No. 1 coil holder. While the end is stopped, the body of the strip is being pulled through the furnace at constant rate by the pulling pinch rolls (7), being supplied

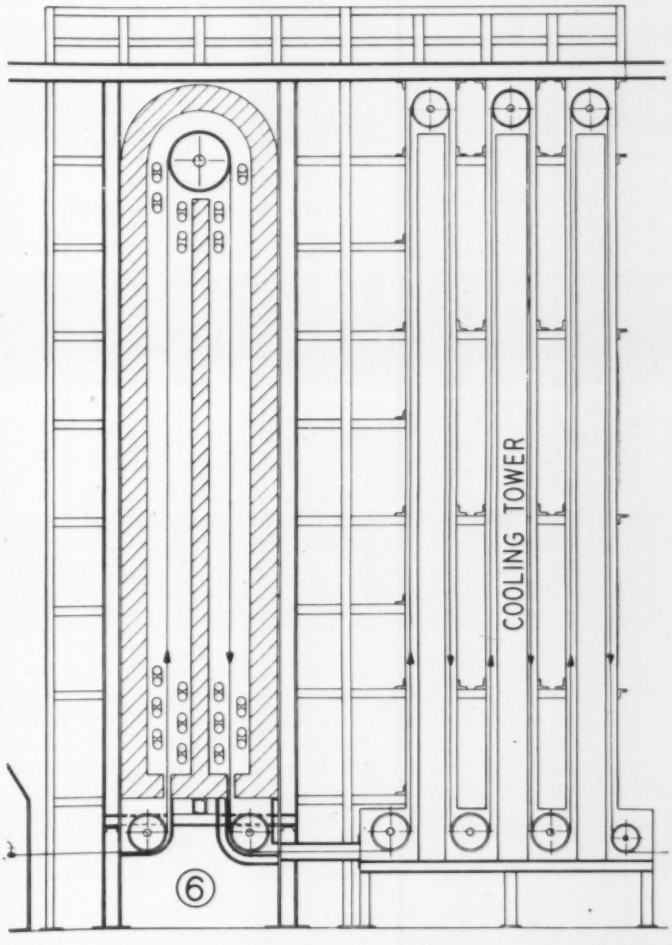


FIG. 4 FURNACE OF STRIP ANNEALER, FIG. 3, WITH COOLING CHUTES

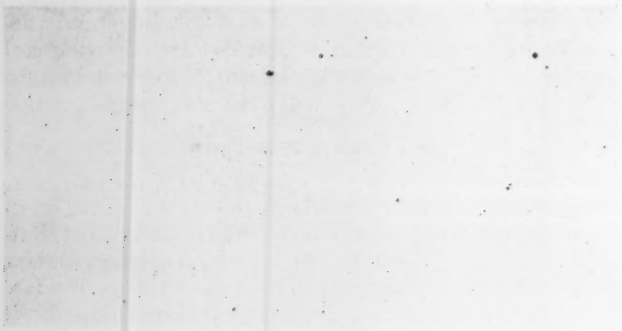


FIG. 5(*a*) RESULTS OF FERROXYL PINHOLE TESTS ON SHEET OF TIN PLATE; ONE SIDE

FIG. 5(*b*) RESULTS OF FERROXYL PINHOLE TESTS ON SHEET OF TIN PLATE; REVERSE SIDE

from the accumulated slack in the looper. As soon as the weld is completed, the upper pinch roll of the combination unit (2) is raised free of the strip, the feeding pinch rolls (4) are started, and normal operation is resumed. It will be evident that the design provides for exceedingly fast coil entry.

After the strip has passed through the furnace and cooler, at such time as it is necessary to cut out a weld and thus separate the ends of two coils which had been joined, the reel and the tension bridle are stopped and the weld is cut out by operating shear (10). Meanwhile the pulling pinch rolls (7) draw the strip through the furnace and cooler at the normal speed, the slack being taken up by the rising of the counterweighted rolls in the mechanical looper (8).

The tail end of the sheared strip is quickly wound on the reel (11), the latter is collapsed, and the coil is quickly stripped from the reel head by means of the coil car and the hydraulic lift. As soon as the retiring coil clears the end of the reel, the belt wrapper is moved into position around the drum and, by means of the tension bridle, the sheared leading end of the strip is fed up to the reel, where it is quickly and automatically entered by means of the belt wrapper. The slack in the looper (8) is taken up by increasing slightly the speed of coiling, and normal operation then proceeds at a constant rate.

Other exit-end arrangements are of course possible, but the one described would seem to be the preferred method.

CLEANING, TEMPERING, AND SURFACE CHARACTERISTICS OF STRIP PRODUCED

In the electrically heated tower-type continuous annealers previously referred to, it was found that no cleaning of the strip was required either before it entered the furnace or after it had left. The oil from the cold-reduction rolls remaining on the strip was vaporized in the furnace and disappeared without leaving any carbon deposit on the strip, or discoloration. The strip coming out of the furnace-and-cooler unit was clean and bright, and could have been tinned directly as it came from the annealer. Actually, it was pickled before tinning.

In order to study the results obtained by cleaning in the furnace and eliminating previous electrolytic cleaning, samples of tin plate produced in this manner were subjected to ferroxyl pinhole tests, with the results shown in Figs. 5(*a*) and (*b*) which represent opposite sides of the same sample. The tin coating was 1.33 lb per base box, and the pinhole patterns indicate a porosity of the coating which is approximately the same as that of regular coke tin plate of equal coating.

The oil vaporized from the uncleaned entering strip does, however, in time build up carbon on the electric heating elements. This deposit is removed by stopping operation for a short time and admitting air to burn out the carbon.

It has been found that the repeated reversed bending over rolls of steel strip at somewhat elevated temperatures results in a definite "tempering" of the strip material, equivalent to mild skin passing or temper rolling. Not only do the results from the furnaces mentioned show this to be the case, but German experiments showed the same, as Prof. Trinks learned during his trip to that country before the war. Thus the temper-tower annealer for some kinds of strip product eliminates not only the slow box annealing but also the expensive electrolytic cleaning and some part of the yet more costly temper passing. Instead of giving the material three or four passes through a skin-pass mill, as is done in the case of box-annealed material in coils, the continuously annealed material need be given only one or two passes. Other expedients now used in connection with skin passing, such as, roughening the cold-mill rolls in the first pass, can be eliminated, since the proper surface condition can be secured in the material by atmospheric treatment in the furnace.

By suitable regulation of the atmosphere, a range of types and colors of surface from that representing bright annealing to a Russian-blue surface, or any intermediate color, can be produced.

PHYSICAL CHARACTERISTICS OF STRIP MATERIAL PRODUCED

When the development of a continuous-strip annealer was first considered, the opinions of metallurgists were sought as to the properties which might be expected in strip material annealed in this manner with a comparatively short heat and cooling cycle. Competent opinion at that time indicated that, once the temperature had been reached, the changes which result in annealing would take place almost instantly, and the same characteristics would be obtained as in box annealing. The required time of the cycle would therefore be merely that consumed in heating the strip to about 1300 F and cooling it down again.

To the author, considering the internal stresses and having in mind Maxwell's law of relaxation of such stresses, it then appeared that factors other than the purely metallurgical might considerably modify this conclusion. Later experiences have shown this to be the case; continuously annealed short-cycle strip material in fact does not have exactly the same physical properties and grain structure as long-cycle box-annealed material. However, it has properties which for many uses are equally good and for some purposes are superior to those of box-annealed strip.

Photomicrographs of samples of strip 0.012 in. in thickness produced by short-cycle continuous annealing are shown in Figs. 6 and 7. The chemical composition of the material was:

C	Mn	P	Si	S	Cu	Cr	Ni
0.06	0.38	0.009	0.024	0.004	0.06	0.024	0.020

The grain structure of the continuously annealed strip is seen to be small and uniform.

More than a year ago, tests of tensile properties, hardness, and ductility were made on nontinned material, designated "black plate," and on tinned material, both produced by the short-cycle continuous-annealing process. The tin plate had higher carbon (0.10) and higher manganese (0.49) content than the "black" material, and was somewhat thinner, having a thickness of 0.01 in. The test samples were taken from the mid-sections of the sheets, and the results are shown in Tables 1 and 2, where L and T indicate longitudinal and transverse tensile specimens, respectively.

In general, the material tested appeared to be fairly stiff, which is advantageous provided it does not mean sacrifice of drawability; and the good elongation results indicated that the drawability should be adequate for many purposes. It was feared, however, that uneven forming might result from the stiffness and that stretcher strains might develop due to the fine grain structure.

Since that time, it has been possible to reduce the hardness. At present, material down to 48 Rockwell is being made by continuous annealing. Indications are that it will be possible to go as low as 44 Rockwell. However, operators have found that, because of the difference of grain structure, the box-annealed and the continuously annealed material can by no means be compared exactly on the basis of their Rockwell-hardness values.

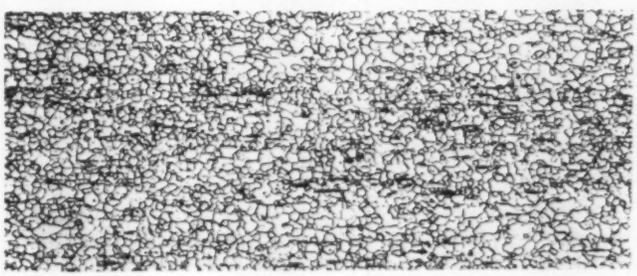


FIG. 6 REPRESENTATIVE CROSS SECTION OF BLACK PLATE, ETCHED; ×100

TABLE 1 TENSILE PROPERTIES AND HARDNESS

Material	Specimen	Elongation, per cent in 2 in.	Lower yield strength, psi	Ultimate strength, psi	Hardness, Rockwell 30T
Black plate	L	29.3	39700	55050	58
	T	27.8	39000	53100	58
Tin plate	L	17.8	58800	61150	66
	T	24.8	60000	61700	..

TABLE 2 OLSEN DUCTILITY TESTS

(Average of three tests)

Material	Total pressure, lb	Deformation, in.
Black plate	1025	0.298
Tin plate	934	0.282

A material of higher Rockwell hardness from a continuous annealer has been found to behave exactly as well in forming operations as box-annealed material of much lower Rockwell number; although some changes in the forming practice may be required. In the plant referred to, all but two classes of strip material are continuously annealed; the exceptions being very thin material (0.0065 in. thick) which is subject to breakage, and material which is to be drawn to form very deep containers, and which must therefore be dead soft.

It is evident, therefore, that the process of continuous-strip annealing has reached a state of development at which tin plate and similar thin material can be produced having characteristics which make it suitable for many uses. Furthermore, development work is continuously in progress which promises to result in a still further improved product.

The use of the process for thicker strip and for other products also seems quite possible.

UNIFORMITY OF ANNEALING

One of the great advantages of continuous annealing is the uniformity of the product produced, as compared with the variability of physical properties from point to point in a coil of batch-annealed strip.

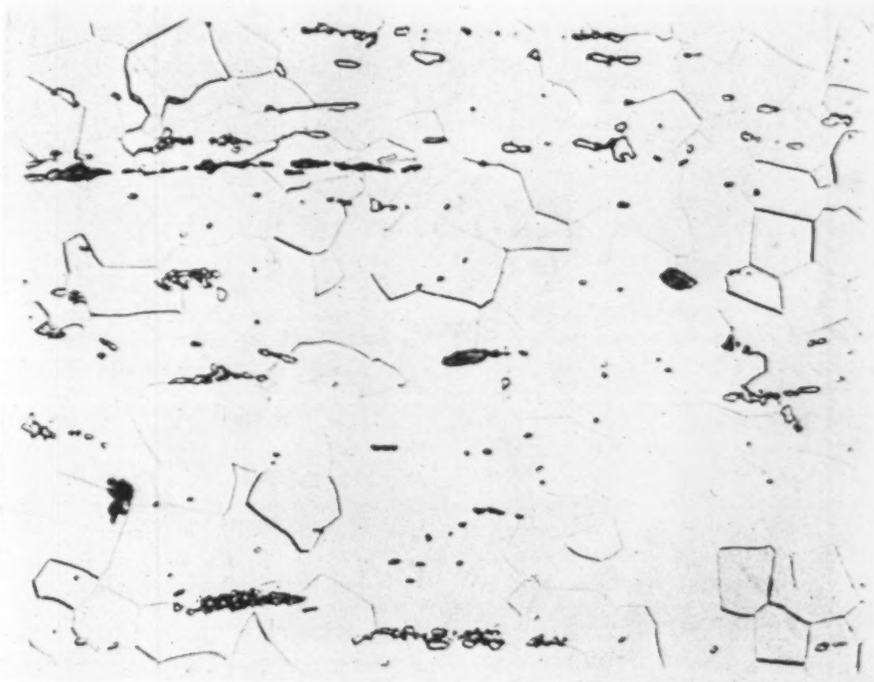


FIG. 7 REPRESENTATIVE CROSS SECTION OF BLACK PLATE, ETCHED; ×1000

It is evident that in batch annealing, points at the outside of the coil and especially at the edges receive heat very readily and are brought up to temperature quite rapidly, whereas, on account of the very low thermal conductivity at right angles to the layers of strip, the interior parts of the coil are much slower in coming up to temperature. In fact, the "soaking time," which comprises the latter half of the heating cycle, is necessitated, not by the requirements of the recrystallization, but simply to allow the heat to penetrate to the interior parts of the coils. Furthermore, since it is usually impracticable to measure the actual temperature at these points, the operators have no way of knowing whether a temperature sufficiently high for annealing has actually been attained there, except by judging from the time cycle.

The inference from this is not that the material in the outer parts of the coil is "overannealed" and the inner parts "underannealed," but that sections from the different parts of the coil differ in physical properties. The tests of Wallace and Rickett,[2] referred to in the Appendix, showed that, while there is little change in softness from 15 min to 2 hr, there is a considerable decrease in the Rockwell number of strip material held at 1200 to 1350 F for 16 hr.

This variation of hardness from place to place in the coil of batch-annealed strip is actually found to exist, and in canmaking it is responsible for making the dies a compromise to take care of both the hard and the soft parts of the strip. If the latter can be annealed uniformly both crosswise and lengthwise, and the hardness remain the same throughout an entire shipment of material, then the dies could be made exactly as they should be made, both for best results in forming and for reduced wear.

The continuous-annealing furnace, with the uniform control of temperature with time which can be effected with gas firing, and the uniformity of heating across the strip width, should provide almost absolute uniformity of annealing throughout.

ADVANTAGES OF GAS FIRING

As compared with electric heating, the most obvious advantage of gas firing is the much lower cost of the heat, which in most plants will not be more than one third the cost of electric energy to do the same job.

A second advantage has to do with avoidance of one of the troubles encountered in electric furnaces, namely, the short-circuiting of the resistors or heating elements by the deposition on them of carbon from the oil vaporized from the strip. It is true that carbon will also be deposited on the gas-fired tubes but, while this will gradually reduce the heat transfer and require a higher tube temperature, nothing equivalent to the short circuiting mentioned can occur; and the time between stoppages for burning out the carbon will be much longer.

A third advantage lies in the much more accurate temperature control obtainable by simple means with gas firing, in the sense of much smaller fluctuations of temperature with time. Electric furnaces are controlled by the "on-off" system, the current flow to the resistors being full on until the indication of the controller pyrometer has exceeded a certain set value, and then being turned entirely off until the pyrometer indication has dropped below another set value, when the current is again turned full on, and this is repeated continuously.

In gas-fired furnaces, proportioning or throttling control can easily be effected by inexpensive means. The gas is not turned full on or full off when slight changes of temperature occur, but is increased or decreased proportionately to the divergence of the temperature from the desired value.

[2] "Annealing of Low-Carbon Rimmed, Aluminum-Killed and Silicon-Killed Steels," by W. P. Wallace and R. L. Rickett, Trans. American Society for Metals, vol. 28, 1940, pp. 333–353.

To be sure, the equivalent of proportioning or throttling control can be obtained in electric heating, but the first cost of the equipment required is so great that few firms have felt that they could use it.

OPERATING COST

The cost of operation of the unit shown in Fig. 4 is estimated to be as follows:

Two operators are required and, assuming a rate of 72 cents per hr and production of 6 tons per hr, labor cost would amount to	$0.24 per ton
Fuel cost, using 1000 Btu gas, 800 cu ft per ton, at 45 cents per 1000 cu ft, would be	0.36 per ton
Power allowance	0.05 per ton
Total	$0.65 per ton

Even after adding the maintenance cost and the fixed charges on a cost of probably $160,000 for the unit, it is evident that the over-all operating cost will be less than 75 cents per ton; and considering that this includes the equivalent of electrolytic cleaning and of a part of the temper passing in addition to annealing, those who have access to figures on operating costs covering these three items in present practice, will realize the tremendous saving which can be effected by using the continuous-annealing process herein described in the fields for which it is suitable.

The advantages of continuous-strip annealing, as compared to present annealing practice may be summarized as follows:

1 Uniform anneal.

2 Uniform surface of strip.

3 Control of the surface of the strip to produce and maintain almost any desired characteristics.

4 Better metallurgical control.

5 Elimination of conventional electrolytic cleaning and, in fact, of all cleaning of the strip before annealing.

6 Tempering with less cold rolling or skin passing.

7 Accurate control of temper produced.

8 Faster operation. A 6000-lb coil can be annealed in $^1/_2$ hr, whereas, with conventional annealing 36 hr or more would be required.

9 Great saving in cost of operation. The continuous annealer is comparable to the present electrolytic cleaner, and would use no more labor than the latter.

10 Elimination of space requirements for storage of auxiliary equipment, such as, annealing bases and covers, when not in use.

11 Reduction of space requirement for storing coils. Coil-storage space will no longer be a problem after the hot-strip storage, except such as is needed preceding the cold-reducing operation.

12 The continuous annealer will lend itself much better to progressive flow of production; it will take material from the cold-reducing mills and furnish it to the skin-pass mill without expensive transfer equipment and crane facilities.

Appendix

After the present paper was written, three references came to the author's attention, having to do with experimental determinations of the time required for short-cycle annealing. The first is the work of Wallace and Rickett,[2] who tested the hardness of low-carbon-steel strip of several different compositions after annealing periods of 15 min, 2 hr, and 16 hr, at several different temperatures; the previous cold reduction of the strip ranging from 18 to 81 per cent. These experimenters found that at temperatures of 1200 to 1350 F, in most cases, practically all of the softening occurred within the first 15 min, and the

decrease of the Rockwell hardness number from 15 min to 2 hr was in most cases negligible. From 2 hr to 16 hr, however, a further decrease of hardness occurred. Each material seemed to have an "inherent softness," below which it was not possible to go. Wallace and Rickett also made photomicrographs of the different specimens.

The second was the work of W. Lamarche,[3] who made tests similar to those just described, and who also found that the physical properties were practically the same after 15 min annealing as after 2 hr. His tests were, however, confined to Armco iron having 0.02 per cent carbon.

The third series of tests, and that most pertinent to the present discussion, was made by Pomp and Niebch[4] on two kinds of deep-drawing strip steel, both having 0.06 per cent carbon. Steel I had 0.31 per cent Mn, 0.009 per cent P, 0.021 per cent S, and was made in an electric-arc furnace, while steel II was aluminum-killed open-hearth steel, having 0.48 per cent Mn, 0.023 per cent P, 0.039 per cent S. The specimens were 0.04 in. thick.

The test annealing of steel I was first carried out in a batch-type muffle furnace, for periods of 1 to 3 min, at furnace temperatures of 1200 to 1650 F and above. The previous cold reduction of the specimens ranged from 10 to 60 per cent. The greater the previous reduction, the quicker the specimens softened when annealed, but those with the higher reductions never became quite as soft as the material had been before the cold reduction, whereas, those with light reductions did. At 1200 F, in every case, within 3 min the material was softened to its lower limit of hardness. At 1380 F furnace temperature, the annealing was practically complete in 2 min for material having 10 per cent previous reduction, in $1^1/_2$ min for 20 per cent and 40 per cent, and in 1 min for 60 per cent previous cold reduction. When it is remembered that the specimens were 4 times as thick as tin-plate stock and therefore required a large fraction of the time for being heated up to temperatures at which recrystallization could occur, it will be realized that the actual annealing must have occurred in a fraction of a minute. There was practically no gain in softness at temperatures above 1380 F.

Pomp and Niebch[4] then tested specimens of both steels I and II in an actual continuous-annealing furnace with a horizontal heating chamber $14^1/_2$ ft long, having three zones, each with a separate automatic temperature regulator. By welding a constantan thermocouple wire to the strip, they were able to ascertain the exact course of its temperature rise as it passed through the furnace. They found that a final strip temperature of 1110 F was decidedly too low, and 1200 F not quite high enough to produce sufficiently quick annealing; also, small variations of final temperature in this range caused considerable variation in physical properties. A temperature of 1290 F was found to be the most satisfactory final temperature, resulting in very effective annealing regardless of the furnace temperature and strip speed with which this final strip temperature was attained.

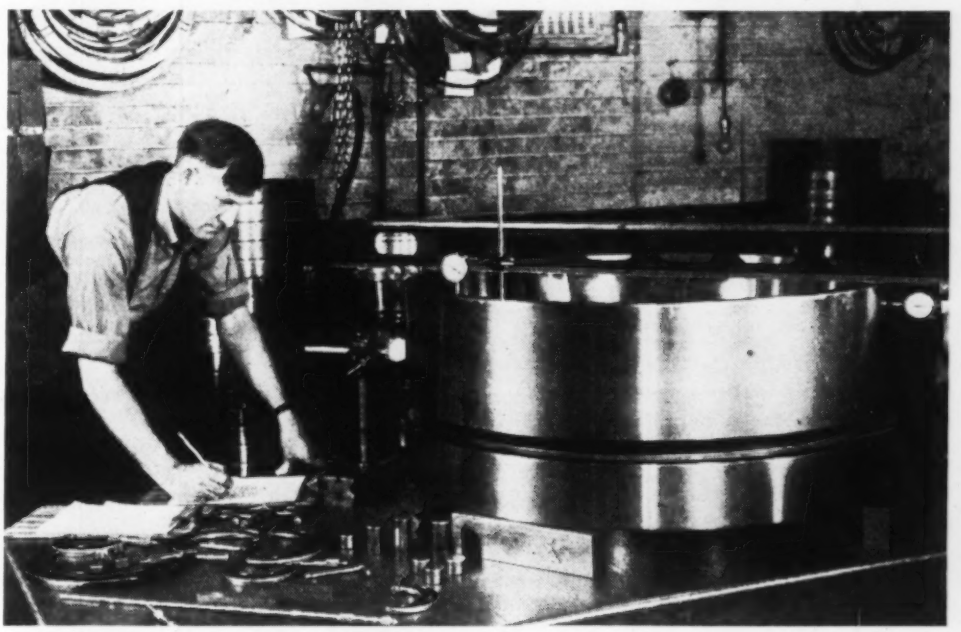
They found that annealing to 1290 F (which temperature was ordinarily reached in $2^1/_2$ min or less, the strip being 0.04 in. thick) usually resulted in very close approximation to the properties of box-annealed material. Steel II, however, was not as amenable to short-time annealing as steel I; in fact, specimens of steel II never fully attained the softness of the same steel when box-annealed. Photomicrographic studies confirmed this finding. Pomp and Niebch therefore concluded that steel to be suitable for short-cycle annealing must have the ability to recrystallize within the short time available. However, they do not seem to have tested the effect of holding the specimens at the final temperature for, say, 1 min, nor the effect of deformation at elevated temperatures.

ACKNOWLEDGMENT

This paper was prepared in collaboration with R. J. Wean, president of Wean Engineering Company, Warren, Ohio.

[3] "Über den Einfluss der Verformungsart auf Alterung und Rekristallisation," by W. Lamarche, *Mitteilungen der Kohle- und Eisenforschung*, vol. 1, 1937, pp. 181–198.

[4] "Untersuchungen über Eignung des Durchziehofens zum Glühen von kaltgewalztem Tiefziehbandstahl," by A. Pomp and G. Niebch, *Archiv für das Eisenhüttenwesen*, vol. 14, no. 4, Oct., 1940, pp. 179–186.



MEN AND MACHINES AGAINST TIME

(Solid steel surface block and numerous small gages used in final inspection of huge precision-made tapered roller-bearing part at plant of Timken Roller Bearing Co.)

SUBCONTRACTING PROBLEMS

How One Company With Four Years of Experience Has Met Them

By L. B. COON

PLANNING MANAGER, SPERRY GYROSCOPE COMPANY, INC., BROOKLYN, N. Y.

SUBCONTRACTING in its present light, which is a means to expansion of output, may be defined as "the utilization of the resources of outside concerns to effect the manufacture of parts for the sole purpose of alleviating an abnormal condition." Although cost reduction and improvement of manufacturing methods are not initial motives in this operation, the prime contractor's standards for both should be at least equally maintained and should any benefits follow, they must, for the purposes of this discussion, be considered only as by-products. The following definition is used at Sperry in order to differentiate between subcontracts and the general large volume of standard purchased parts. A subcontractor is "any supplier that is a substitute manufacturer for this Company, that is, one who does work that would normally be performed in our own plant in normal-capacity operation."

To the prime contractor, greater channels of expansion have been opened without the fear of costly readjustments that will affect financial structure made top-heavy by excessive investments in new plant facilities. Half of the machine tools in the country are located in small shops. Obtain access to them and you can measure your capacity in extremely large figures. But have no illusions. There is a necessary stage of orientation and education which is too often either rushed or overlooked. I cannot emphasize too strongly that excessive initial optimism will often represent the difference between final success or failure.

To the small plant, subcontracting makes available a share in the defense program without the accompanying organization necessary to negotiate and deal directly with the government.

To the defense plan itself, greater and more efficient production is imparted. The larger organizations, by acting as prime contractors, are taking over in their own hands this business of ferreting out the apt source of supply. They are, in a sense, acting as purchasing agents for the government, and I do not hesitate to say that they will do a more efficient job. They are just naturally, by experience, better qualified.

To the nation as a whole, greater economic stability is guaranteed. Large prime contracts can be broken down into numerous small specialized orders which will serve to decentralize into the smaller industrial communities.

SUBCONTRACTING BY SPERRY DATES BACK TO 1937

The initiation of the present era of subcontracting in so far as Sperry Gyroscope is concerned, dates back to the spring of 1937. We were at that time working closely with the various supply arms of the government in evolving a plan for emergency procurement of products.

The theme of the entire plan amounted to a survey of any existing facilities of outside plants which could be used to supplement Sperry equipment in the event of rapid expansion. In conjunction with the procurement divisions of Air Corps and Ordnance, New York offices, hundreds of plants were surveyed. The unsatisfactory ones were discarded after an initial visit, owing to the type of equipment or lack of the right kind of experience. Those offering possibilities were closely analyzed and tabulated. Their machine-tool equipment was classified and specific parts or types of work were theoretically assigned to them. Although the plan never materialized in its entirety, many of the companies mentioned in the original allocations are being utilized today to great advantage. Educational orders were first placed in June, 1937, when a small shop in the neighborhood was called upon to manufacture a handful of parts on a then recently received Air Corps contract. There were at most 2000 hours of labor involved in this transaction, and I say it was educational because there was no vital necessity for an outlet at that time.

In the two years that followed, this program of preparation was followed up at every opportunity. By April, 1939, 25,000 hours per month were flowing in from 21 sources of supply. By this time, all the problems of quality control, cost, methods, and the like, had been met and handled on a small scale.

By October, 1939, expansion had started in earnest and 60,000 hours per month were being performed at 23 sources. July, 1940, saw an increase to 170,000 hours per month from 35 sources. At present (April, 1941) we are receiving a quarter of a million machine-hours per month from 48 outside concerns and present indications are that this must be at least doubled by the middle of 1942. Preliminary arrangements and educational orders are now under way with several new sources which will absorb a large portion of the increase. In general, the program on the outside will bear a ratio to the total of one to three. This means that one third of all machine output will be handled by our subcontracting organizations.

PLANNING A SUBCONTRACT PROGRAM

Before the adequate mechanics of any subcontract program can be worked out, a reasonably accurate statement of how much shall be subcontracted must be prepared. This is accomplished by projecting a sales forecast upon a statement of unfinished business, not only in labor hours but also broken down by types of work—milling, drilling, lathe, assembly, and the like. This total is then scheduled out for the ensuing months so as to constitute a machine load. The actual plant capacity per month is then set against these requirements. The overflow figures indicate the total hours to be subcontracted, how much of each type of work shall make up this total, and in what months they are required. As sales predictions are altered this forecast is revised.

In the general over-all planning for expansion, a policy has been formulated which provides that in future operations, one third of all machining labor shall be subcontracted. Additional floor space, as well as new equipment, is ordered in accordance with this plan.

While this is only preliminary planning in a simple form, it is absolutely essential. Without these resultant figures, the prime contractor cannot even start to plan subcontracts. He has no

Presented at the Management Defense Conference, Philadelphia, Pa., April 22 and 23, 1941, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

Another article on the subcontracting experience of the Sperry Gyroscope Co., Inc., "Quantity Production of Gyro Instruments," by P. R. Bassett, appeared in the February, 1941, issue.—EDITOR.

indication either of what type outlets to seek or of what magnitude they should be. Even over and above this, preliminary planning will insure against the need for eleventh-hour subcontracting after an internal bottleneck has developed which is usually too late. It will also prevent the farming out of too much work and consequently idle machines in the prime contractor's plant. This condition would increase costs and have a bad psychological effect.

SEPARATE ORGANIZATION SET UP FOR SUBCONTRACTING

Contracts with other prime contractors as well as our own experiences have proved that a separate internal organization must be set up to control all subcontracting operations. At Sperry we have even gone so far as completely to divorce this function from our purchasing department.

The head of this subcontracts department reports directly to the planning manager. This man should primarily be a methods engineer with adequate mechanical experience and should possess a native ability to manage. These qualifications are necessary when we consider the fact that, indirectly, he is acting more or less in an advisory capacity for a number of outside plants, by assisting in their planning, tool design, quality, and cost control.

Another essential qualification, of slightly lesser importance than the previous two, is the ability to make personal contacts and detect any structural flaw in the organization of a subcontractor's plant. In most instances at Sperry he is usually relieved of this by preliminary surveys made through others in the organization. These surveys usually include a comprehensive study in the given plant of the mechanics of their production control, scheduling system, machine load, inspection, routing, and financial setup. If a serious omission or lack of control is evident at any of these points, corrective measures are recommended and must be followed through before the association can get beyond the educational stage.

The detail survey is usually completed by a staff of methods engineers reporting to the subcontracts supervisor. These men are responsible for reporting on the adequacy of the machine-tool equipment. From the subcontractor's normal commercial product, they can usually determine his ability to work to the required tolerances. They also report on the size of the plant, floor space available, equipment, and possibilities of expansion.

A staff of clerical workers, reporting to the subcontracts supervisor, is also maintained whose duty it is to record progress and machine load at each company. Each month a report is prepared showing for each company and for each part subcontracted to it, a complete record of actual performances plus future requirements. These schedules are, of course, closely coordinated with our own factory planning.

A group of production expediters or follow-up men, as they are commonly called, also report to the subcontracts supervisor. They are constantly circulating throughout their assigned plants for the purpose of insuring maintenance of schedules. It is usually upon their recommendations that Sperry methods engineers are called upon to visit an outside plant where trouble has developed. They will closely watch shop schedules and machine loads for possible bottlenecks and choke points. From time to time they will facilitate production by procuring material or tools for the subcontractor. We have had several cases where the follow-up man has been instrumental in installing dispatch and routing systems. In one particular plant, a duplicate of our entire system for routing, dispatching, and scheduling was installed. In several of the smaller plants, personnel problems and assignment of man power for increased production are discussed with their management. In short, it is through the medium of these men that the much greater resources of the prime contractor are placed at the disposal of the smaller plants when the occasion necessitates.

The three groups mentioned constitute, at Sperry, a staff of about sixteen persons reporting to the subcontracts supervisor. There are, of course, in addition to this, many other departments in the organization, which contribute man power to the subcontracting program. Primary among these is the inspection department.

HOW INSPECTION IS CARRIED ON

At the start, all material received from outside sources was inspected at the Sperry plant. In a great many cases, this resulted in subsequent rejections and necessitated return of material to a supplier with detailed explanations and advice as to correction. Owing to the widespread location, two serious problems arose, namely, the control and return of all rejected material, and the inability properly to explain the reasons for rejection and corrective measures to be taken. The solution has been to station inspectors at the subcontractor plants. Parts are approved before they leave the source of supply. By constructive inspection, errors are detected soon enough to save considerable time and money. The inspectors selected for this post must in general be of higher caliber than inspectors stationed in the home factory. Their function is to see that the subcontractor's inspection is working effectively. At the present time, 27 Sperry inspectors are maintained at outside plants.

After the finished parts have left the subcontractor's plant, they are not, as such, inspected in the home factory but go at once into the assembly line. As subassemblies, they will later on be subjected to functional tests.

In addition, the product engineers make periodic visits to the subcontractor's plant for the purpose of passing judgment on questionable items. Usually this need only continue for a short time until the engineer has formulated certain policies which the inspector may then utilize as a basis for decisions.

METHODS DEPARTMENT'S RELATION TO SUBCONTRACTORS

Another group, which actively concerns itself with subcontracting is the methods department.

It is the function of the methods department to work out on paper, in connection with each part which is to be made, all the operations which must be performed, all the tools which are to be used, how much time should be allowed, and so on. There are men in this department who are specialists in each type of product. Basically, of course, the methods worked out should apply to all work done on a given product whether in the home plant or in the plants of suppliers. However, a difference in machine-tool equipment may alter this condition and the subcontractor will have to work out new methods of manufacture. In these cases, a methods engineer from the methods department will be consulted.

The methods department is also concerned where subcontractors are authorized to make expenditures necessary to maintain or alter special tools loaned them. In the case of tools too commonly used to be available for loan, they are supplied with designs and authorized to manufacture duplicates. Sometimes they are even allowed to proceed according to their own design. All these operations are carried out subject to the approval and under the guidance of our own methods department.

To facilitate traffic and materials handling, by careful planning, many time-saving practices can be worked out whereby one subcontractor's equipment may be used to supplement the work performed by another. While it is not ordinarily deemed good practice to have two different plants contribute to the machining operations on the same part, we have many cases where three plants in the same locality will perform the casting, machining, and plating, respectively. In these cases where

subcontractor plants are foundry-equipped, they are loaned patterns and allowed to supply their own casting.

One particular company was aided in the installation of an anodizing plant for applying special finishes. All the subcontractors in that vicinity will now be able to utilize this equipment and thus be able to supply completely finished parts. An added advantage is that the way is now clear, should it prove necessary, for these plants to supply subassemblies.

This decentralization of complete subassemblies to subcontractors, while not as far advanced as detail-part manufacture, is rapidly taking shape and will soon be available as an outlet for the prevention of overload on our own assembly facilities.

Cost control must also figure prominently in all operations. Subcontractors sometimes overanxious to start relations will underquote. This is partially due to wishful thinking as well as inexperience with strange products. The prime contractor should assist in preparing these quotations using as a background his own actual cost experience with the part in question and should never allow these negotiations to proceed unless he is reasonably sure that a fair profit is guaranteed the subcontractor.

No set prices are made with new subcontractors until the educational stage is over. They are usually started off on a time-and-material basis and prices are worked out after they have had preliminary experience. In order to eliminate the customary delay involved in obtaining and checking quotations, a very flexible system has been instituted with some of the well-established subcontractors. This consists of working out a money rate per hour for each plant by carefully considering their wage scale, burden rate, and reasonable profit. They will then apply this rate to the predetermined Sperry time estimates which are furnished them and invoice accordingly. This has worked out very well so far and in only one or two isolated cases have later adjustments been necessary. If materials are not furnished by the prime contractor, the subcontractor should be allowed a handling charge.

NUMBER OF SUBCONTRACTORS MUST BE INCREASED

As previously indicated, the volume of subcontracting must rise sharply in the near future. The Sperry Gyroscope Company alone will have close to 4000 men at outside plants. This does not include the accompanying overhead labor required at these plants. This expansion cannot be handled entirely through the medium of large subcontractors. One of the problems at hand now is to reach out into small industrial areas and coordinate the equipment of several small shops. A group of small plants, no one of which has the rounded equipment necessary for an order, can be grouped into a capacity pool to act as a unit. Any one of the plants, or better still, this unit, should be headed by a capable person who would act as central contact for the group. While this may not have the advantages of one plant absorbing a complete subcontract, it is one way to put the complete industrial capacity of this country to work.

SCOPE OF SUBCONTRACTING SUMMARIZED

In summation, therefore, the following six points may be established as the general scope of all subcontracting operations:

1 Preliminary planning is essential for determining subcontract requirements.

2 The regular organization is not adapted to absorbing the subcontract program. Greater control can be obtained through the medium of a special structure.

3 A systematic and thorough training period will pay dividends.

4 Evolve a flexible system of cost control which will insure a fair profit to the subcontractor, without necessitating lengthy and time-taking negotiations.

5 Maintain close personal contact between both organizations to insure delivery and cost control.

6 Do not in any case "walk away" from the subcontractor's internal difficulties. Accept them as your own and lend assistance.

MEN AND MACHINES AGAINST TIME

(Cincinnati No. 2 centerless grinder, a peacetime machine tool known for its ability to grind a variety of parts, has been adapted to the grinding of the bourrelet diameters of 155-mm high-explosive shells weighing about 75 lb.)

Administrative ORGANIZATION *for a* SMALL MANUFACTURING FIRM

By WILLIS RABBE

ASSISTANT SUPERINTENDENT, THE UPJOHN COMPANY, KALAMAZOO, MICH.

IN attempting discussion of a management subject, one is confronted with the necessity of finding a common understanding of the terms to be used. While management of the activities of groups of people is as old as the oldest civilization, its practice has been handed down the years as an art and not as a science. It is only in very recent times that our schools of technology and scientific societies have included management subjects for study and discussion.

It may well be that this will result in evolving a science of management with well-defined terms and irrefutable laws, but at the present time no such agreement exists and it therefore seems fitting that a discussion of administrative organization begin with a defining of terms to be used.

DEFINITION OF TERMS

Administration may be defined as the planning, directing, and controlling of activities. Since most businesses have a corporate form of organization to satisfy the legal requirements of conducting their affairs, and since the same individuals often have positions in both corporate and administrative organizations, the purposes of each are often confused, particularly in smaller companies.

Organization may be defined as the classification or grouping of activities for purposes of administering them. Organization is to business what the nervous system is to the human body. Its purpose is to send instructions (impulses) to the operating members and to receive and transmit to top management (the brain) information which will enable it to function intelligently. The analogy may be carried to the point that if any part of this "nervous system—administrative organization" is blocked or permitted to atrophy, then the activities controlled by it will also wither and die.

For the purpose of this discussion "small" is taken to mean a company employing several hundred to a thousand people.

REQUIREMENTS OF GOOD ORGANIZATION

In our approach to the problems of administrative organization for a small manufacturing company, our first consideration should be the requirements of good organization. These are fundamental for all business since the activities performed by any type of business are the same regardless of the size of the enterprise. It is only the scope or extent of activities which vary with size.

The basic requirements for administrative organization may be stated briefly as follows:

1 There should be centralized control accompanied by proper delegation of authority over all the activities necessary to operate the business.

2 Definite responsibility should be fixed for the performance of each activity.

3 Authority should be granted commensurate with the responsibility delegated.

4 Responsibility and authority should be delegated for related groups of activities in order to promote specialization.

5 The number of subordinates reporting to each executive should be limited so as to permit concentration on long-range plans and training of subordinates.

6 The distinction between direct and functional authority should be clearly recognized.

7 Coordination of the specialized activities of the various groups should be provided so as to assure realization of the company's objectives and prevent factionalism.

8 Members of the organization must be trained to think of their own problems in terms of the plan of organization.

PROBLEMS OF ORGANIZATION

The purpose of this discussion will be to consider the problems of organization for a small company in satisfying these fundamental requirements.

There are several common ways in which to approach business problems. Among these perhaps the most common is on the basis of personal experience. Another is on the basis of statistical or historical information. A third method often used is that of considering a single activity without regard to its relationship to other activities and to the business as a whole.

A preferred method is one which the late James O. McKinsey evolved and which may be called a categorical method. All business problems, according to Mr. McKinsey, fell into one or more of six categories and these categories were to be considered in a fixed sequence of importance. These six are: Policies; organization; personnel; facilities; techniques (or methods); and public relations.

Among the advantages of this method is that it enforces consideration in a logical sequence with things of first importance receiving first consideration. It indicates that in Mr. McKinsey's opinion, at least, organization is second in importance only to broad questions of policy. Yet many managers particularly of smaller enterprises concern themselves with problems of facilities and methods for carrying on the necessary activities of their business without first considering adequately the problems of organization involved. Organization might truly be called the keystone in all considerations of business problems.

DESIGNING A PLAN OF ORGANIZATION

Having established the importance of organization and agreed on the fundamentals of good organization we may proceed to discuss the problems of designing a plan of organization for a specific company.

Contributed by the Management Division and presented at the Semi-Annual Meeting, Kansas City, Mo., June 16–19, 1941, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

The first step in designing such a plan is to consider the activities necessary to carry on the business. That is where the trouble starts, for most of us cannot think of activities apart from personnel. Therefore, we are apt to design from the point of view of accommodating our present executives rather than confining our thinking, at the outset at least, to providing a basic document for reference in solving organization problems which will arise in the future.

A second mistake which we are apt to make, again thinking in terms of personnel, is to fail to provide for future expansion. We cramp our plan because we know we do not have and cannot support a large executive personnel. Nevertheless, all of the activities which must be performed if the business is to be operated successfully and to grow must be provided for in our plan.

If we do a real job of preparing this organization plan we will be in a much better position to make the adjustments necessary to meet existing conditions. We can regroup activities, if necessary, so as best to utilize the personnel available at the moment. We can intelligently strengthen the weaknesses of the existing executive personnel if we are aware of the larger job to be done. Above all we should avoid assigning to the chief executive or general manager duties which should be delegated. A very common error is to force the general manager to assume direct responsibility for many details when the problem of organization is not thoroughly considered.

ACTIVITIES OF GENERAL MANAGER

It should be realized, when the great array of activities called for by the basic plan are considered, that the general manager must reserve for himself three important functions:

1 Long-range planning for the business.
2 Coordinating all the ramified and specialized activities.
3 Controlling these activities so that the company's objectives may be met with reasonable expenditure of funds and efforts.

This means that the general manager must reserve for himself sufficient time:

1 To think about the larger problems or policies of the business.
2 To consult with subordinates and outsiders for the purpose of gathering information on which to base decisions.
3 To teach others the art of management.

How few general managers, particularly of small enterprises, allow themselves sufficient time for these three very important activities. Most of them are so busy doing "things" that they have no time to think, to consult, and to teach.

DELEGATING RESPONSIBILITIES

Having rearranged the ideal plan of organization to meet existing conditions, the next point is assigning or delegating responsibilities for the various activities planned. It is at this point that one is faced with the manifold inadequacies of the executive force immediately available. It is at this point of development that one is most sorely tempted to take on, as general manager, the direct responsibilities for overseeing some detailed activities. However, if one is of stern enough stuff and fully understands the real function of a general manager, one will deny himself this easy "out." Instead he will first consider if the executive pay-roll budget won't stand a few trainees in the art of management so that limited responsibilities can be assigned to them. The general manager can guide these trainees, as a teacher, in learning the art of exercising authority, and thus he may gradually expand the responsibility and authority assigned to them.

Just what is the difference between a general manager's taking on these duties personally and his assumption of the task of training another for the job? It would seem obvious that in the latter case a definite provision is being made for the future. The general manager will handle matters in an entirely different manner if he is training someone for the task than if he has assumed the responsibility himself.

Some managers in such situations are apt to consider stealing an executive with a reputation from larger and better staffed competitors. That costs dearly and is usually a most unsatisfactory solution. The possibilities of assigning some responsibilities to consultants or outsiders on a retainer or a fee basis might be considered. This has some advantages which will be amplified later in our discussion.

Of course, there is always the possibility that the executive personnel is so versatile that they can be required to "double in brass," so to speak, and carry on several not too closely related activities at the same time.

The advantages and disadvantages of each of these four possibilities, may be stated briefly as follows:

If the general manager assumes responsibility for and authority over any of the specialized activities of the business, the lack of coordination and planning will probably result in a gradual assumption of one-man rule in which all decisions are made by the general manager and the business gradually retrogresses because no one has time to think of the long-range problems or to train others to make decisions and assume authority. The advantages in such an arrangement are all very narrow and short-range in scope. It does save executive pay-roll; it simplifies control and provides for the utmost use of expediency. The trouble is that the business usually dies with the "old man" and he dies early because of overwork.

If consultants are used, a large experience and talent is available which can be used or not at the election of the general manager. This talent, if used on a full-time basis, would be very expensive. Top management is more apt to accept the recommendations and advice of consultants because of their reputation and competence. At any rate their service can be dispensed with whenever management feels like it, or so they think. However, it must be apparent that the continued use of consultants over any long period will increase the void in organization rather than remedy it, for no personnel is being trained to assumed increasing responsibilities.

The expedient of "doubling in brass" probably is resorted to in most cases in small organizations. If the general manager is wise in the art of management and knows when to stop working a willing horse beyond endurance, the results are usually adequate. However, an undesirable accompaniment is that traditional associations of dissimilar activities persist and rights to exercise authority over certain provinces of the business by certain individuals become established. Also a greater degree of control must be exercised by the general manager because of the tendency of individual executives to favor one specialty and to neglect others.

The use of younger, perhaps not yet completely qualified, executives has, obviously, much to recommend it. However, it will fail miserably if the general manager has no love for or understanding of the teaching art. If he is one of those industrialists skilled in the use of expediency and the playing of hunches, if he is not himself a student of management and proficient in the practice of the art, it is not reasonable to suppose that his subordinate will be well trained to assume greater responsibilities or to exercise greater authority. However, if the general manager is a master of the art and has a love for passing it along to others, he and his company will be blessed with as loyal and inspired a type of management as it is possible to obtain.

TEN ACTIVITIES OF A MODERN BUSINESS

To be a bit more specific about this matter of assignment, there are ten distinct, essential activities which must be performed in any modern manufacturing business. These are as follows:

(1) Sales; (2) finance; (3) production; (4) accounting control; (5) product research; (6) quality control; (7) industrial relations; (8) office services; (9) construction and maintenance; and (10) legal counsel.

Every business regardless of size will have to provide for these activities and, of course, many subordinate activities.

Of these ten, three—sales, production, and accounting control—are so traditionally accepted as primary activities that we will merely state that they should obviously be assigned to full-time employees of the company. However, the general manager of a small enterprise is apt to be a specialist in one of these activities and, therefore, be tempted to assume the authority over his specialty. Let us hope he is a real student of management and resists the temptation.

Finance, product research, and industrial relations are becoming more and more accepted as activities of primary importance to good industrial health. These might well be assigned to our so-called trainees in management provided the general manager is skilled in selection and proficient in teaching. They do not lend themselves readily to combination with other activities or to the exclusive use of consulting services. No large number of people is required to perform these activities and sufficient time for consultation and reflection is usually available before action must be taken so that less seasoned men could head these activities.

Quality control and construction and maintenance are two activities which are often assigned to the chief production executive. Personally, I feel that it is very poor practice to assign quality control to a production executive for the same reason that a bookkeeper should not audit his own accounts. However, if the chief production executive assigns the responsibilities of production supervision, quality control, and maintenance to three or more competent individuals so that he is not controlling his own activities, then I feel that an effective compromise with best practice might be made in the interests of pay-roll economy.

The activities grouped under the heading of office services, such as stenographic, filing, switchboard, messenger, and the like can be, and frequently are, assigned to either the financial executive or accounting executive on the basis of availability for the added responsibility.

In most companies, of the size under discussion, it is usually desirable to utilize services of an outsider for legal counsel. However, if an individual of proper training is available the financial and legal responsibilities can often be satisfactorily combined. In these days of more and more regulation by innumerable commissions as well as by orthodox legislative bodies, activities properly assigned to a legal counsel must be provided for.

USE OF COMMITTEES

The plan of organization should also provide for duly constituted committees. One of the objections to committees is that they "waste so much time." This objection can be overcome if members of the committee will realize that their function is the exchange of information and not the settling of old scores and petty differences.

The important administrative problem of coordination can be partially satisfied by the provision of such committees as budget, new products, employee information and training, purchasing, and the like. Of these the budget committee is most important as a coordinating body.

All major activities of the business should be represented in the committee. The principal responsibilities assigned to the committee should comprise:

1 Approval of budgets.
2 Inquiring into underlying causes of budget deviations.
3 Discussion of long-range plans as well as immediate problems of the business.

Even small businesses should be able to afford an hour or so a month to devote to such coordinating efforts.

SPECIALIST ADVISERS

So far our discussion has been concerned with the administrative function of the business. Every executive, however, finds himself performing two types of activity, namely, administrative work and staff work. Staff work is concerned with studying problems and determining solutions for them. As an executive's administrative duties increase owing to growth of the business and as the problems requiring his decisions become more complex, he finds increasing need for more time to study these problems and specialized information to solve them.

This need is best satisfied by the use of specialists who are associated with him in the capacity of advisers. These specialists usually have no administrative responsibilities. Indeed, their advantage lies in the fact that they have time for research because of freedom from routine duties.

Businesses, of the size covered by our discussion, probably will not find a pressing need for staff assistants. However, the basic plan should envision growth and, therefore, provide for them. The executive should understand their proper use and their relationship to other units of organization.

ORGANIZATION CHARTS

The last step in the development of a plan for administrative organization is the preparation of organization charts. Such charts are among the fundamental tools of management. The pity is that most of them are so poorly conceived and generally serve no more useful purpose than decorating the office walls.

All of the constructive thinking of top management should be done with the plan of organization in mind for it is only through this plan that such thinking can be translated into action.

It is by consistent study and training in the basic concepts of organization in general, and the company's adopted plan in particular, that individuals can work for the maximum benefit of the company as a whole. If a chart of the ideal plan of organization is made and discussed frequently with the key executives, the task of fitting periodic personnel changes into the plan will be simplified.

Companies are operated by individuals, it is true, and it has been said that an institution is but the lengthened shadow of a man. However, a little reflection should lead to the conclusion that the success of any undertaking as complex and specialized as a modern commercial enterprise must result from the cooperative effort of many individuals. The individual who will contribute most to the continued success of the business is the one who is capable of solving its problems in terms of the business as a whole, and not the one who is outstanding in his specialty. In short, the one who understands good organizational management. Most businesses, and particularly smaller ones, have difficulty in uncovering and training good material for general management. The subordinate executives are all immersed in and trained for their specialty.

It is therefore necessary that all the individuals who comprise the executive personnel of a company be taught to understand and use the plan of organization as a reference docu-

ment and to think in terms of relationships of activities, and not only in terms of specialized functions and personalities. If this is done, the problem of succession for the general manager will be simplified, as the one who shows the greatest aptitude for thinking in terms of the company's future and in training his subordinates to think in terms of company organization will have demonstrated his grasp of general administration.

In my opinion, the use of organization charts for training is hindered when names and titles of individuals are given too much prominence. Names and relationships of activities to be performed should be the primary purpose of the chart. Names and titles of individuals should only appear in a subordinate position and character. Such a chart should be an incentive to the younger and lesser individuals to prepare themselves for greater responsibilities, particularly if some activities are shown as unassigned or several are delegated to one individual. It is unfortunate that so many textbooks on management and organization use charts with titles such as president, vice-president, treasurer, purchasing agent, and the like, rather than a word or phrase descriptive of the function which the bearers of such titles are supposed to perform.

SUMMARY

The conclusions which I hope we have all reached as a result of this discussion may be summarized briefly as follows:

1 Organization is one of the primary problems of management. It is the means by which the natural tendency of individuals to specialize and segregate can be directed toward concerted action.

2 Problems of organization should be considered in terms of activities to be performed and not in terms of personalities involved.

3 There should be available a basic or "ideal" plan of organization for reference in considering organization problems.

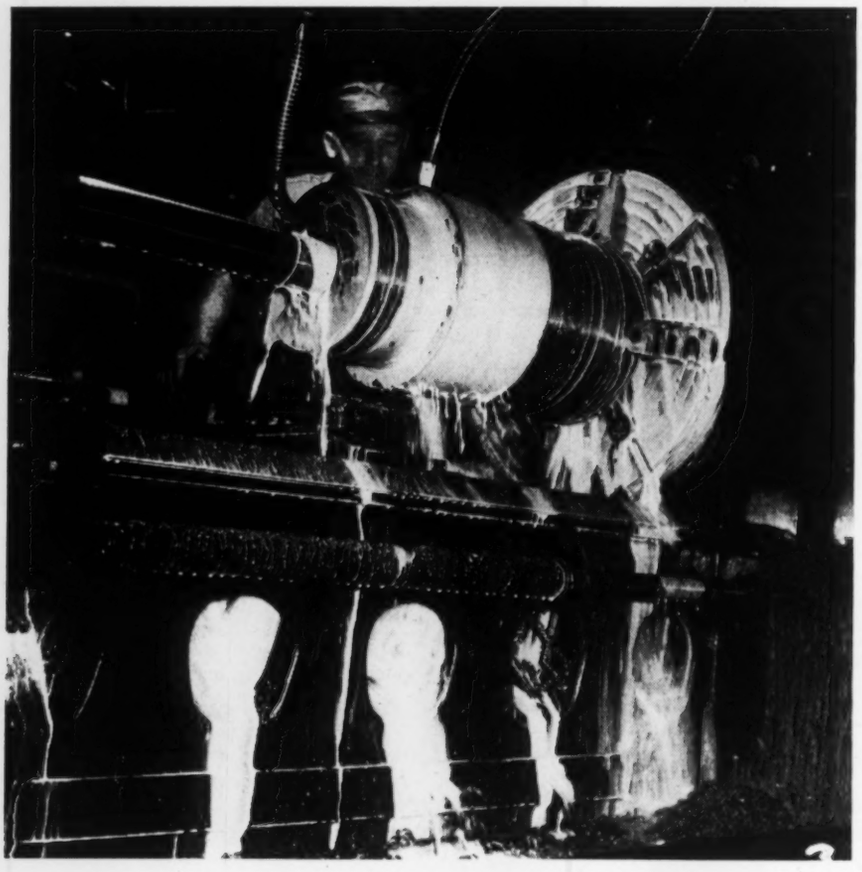
4 Modifications of the basic plan to meet conditions of the moment should always be made from the point of view of approaching the ideal plan at the earliest possible moment.

5 Of four possible solutions to the problem of assigning responsibilities to an inadequate executive personnel, that of assumption of the responsibility by the general manager is least desirable. Assumption of responsibilities for several unrelated activities by existing personnel may be a practical compromise, but the use of "trainees" under the direct supervision of the general manager is a recommended solution. Reliance on the exclusive services of consultants for major activities is only feasible under certain restricted conditions.

6 The use of committees should be recognized in the plan of organization. No business is too small to make effective use of a budget committee.

7 A major responsibility of the chief executive or general manager is to teach his staff the fine art of management; particularly the principles of good organization.

Finally, it is only through good organization that personnel and facilities can make company policies effective.



MEN AND MACHINES AGAINST TIME

(The steel forging being machined on this 4-A heavy-duty Warner & Swasey turret lathe is a forging machine pinion weighing 1030 lb. The milky-white liquid is a coolant that constantly flushes over the work to keep it cool while under cut. The piece is being turned and bored to close limits at the same time.)

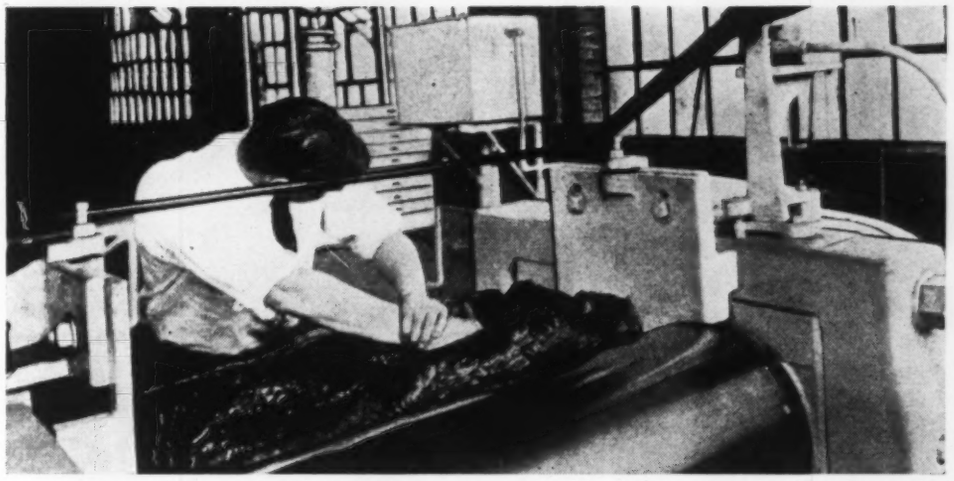


FIG. 1 WHILE IMPROPERLY CUTTING MATERIAL TOO CLOSE TO BITE OF ROLLS, OPERATOR'S KNIFE AND HAND GET CAUGHT IN MATERIAL; HE HAS USED HIS FREE HAND TO TRY TO FREE THE OTHER, AND HAS OPERATED SAFETY BAR WITH HIS HEAD

Safety Features on MILLS *and* CALENDERS *for* RUBBER *and* PLASTICS

By J. MILWARD

SALES ENGINEER, WM. R. THROPP & SONS COMPANY, TRENTON, N. J.

THE materials used in the manufacture of rubber and plastic articles are mixtures of basic crude materials and various other ingredients. In the rubber industry, these basic materials are crude rubber or crude synthetic rubber[1] and, in the plastic industry, they are the various plastic polymers. The ingredients added to these crude materials are essential to proper processing or are necessary to produce the desired result from heat-treatment or are added as inert fillers or reinforcing agents. The mixing is accomplished while the crude material is in a plastic state. Although large internal mixers of various types are used for heavy production, the equipment used in the greatest number of mixers consists of a pair of iron rolls geared together and turning toward each other. Furthermore, the equipment is usually fed by hand. It is heavy equipment and its operation is accompanied by the pronounced hazard suggested by Fig. 1. Calenders, which are used for frictioning and sheeting, as well as other specialized roll equipment (1),[2] present a similar hazard.

The plastic milling of materials requires tremendous power and there is an ever-present danger that a careless operator may be caught accidentally while handling the material on the machine. Inasmuch as the equipment is unique to the rubber and plastic industries, the design of safety equipment is also unique to this class of machinery. This safety problem has three important phases.

The first of these is the design of power cutout and adequate braking in order to stop the equipment quickly and without damage. The second is a suitable arrangement of tripping devices so located that almost any involuntary movement by an operator in distress will stop the machine. The third phase of this problem is largely a question of the employer's responsibility to his operator by installing and maintaining the best available safety equipment.

The first rubber mills had no power cutouts, no brakes, and no method of stopping except by throwing an obstruction into the bite of the rolls. This has frequently been referred to as a "crowbar" brake. Although the method often would stop a mill the operator did not always have within his reach a suitable implement to throw into the bite of the rolls. When such an implement was found, the inevitable result was severe damage to the rolls or frame of the mill. After stoppage of the mill was accomplished, however, it was not certain that fracture of one of the rolls would not permit rotation of the portion of the broken roll on the gear end. This was obviously an inadequate method of braking from several points of view.

The first important advance in equipment was the introduc-

[1] Synthetic rubber is actually a misnomer for rubber-like materials which have some of the properties of rubber. Usage has apparently established the term, however inexact, as a designation for a growing variety of new materials.

[2] Numbers in parentheses refer to the Bibliography at the end of the paper.

Contributed by the Process Industries Division, and presented at the Annual Meeting, New York, N. Y., December 2–6, 1940, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

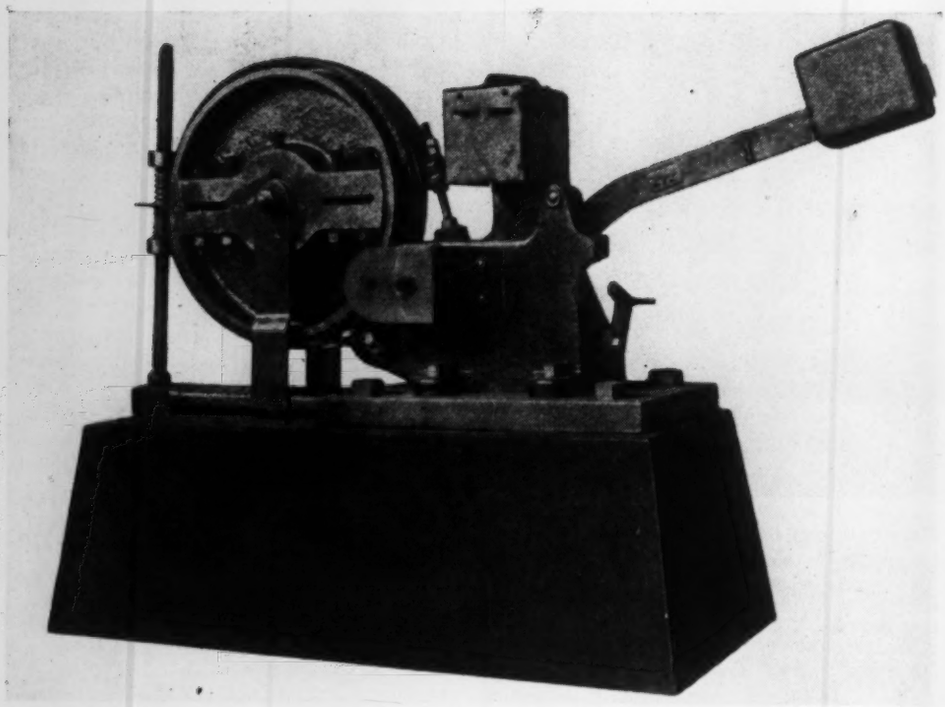


FIG. 2 ESSENTIAL PARTS OF A MECHANICAL BRAKE ELECTRICALLY HELD

tion of a throwout clutch on the high-speed drive shaft. Then, even after the clutch was disconnected, the rolls might be carried through several revolutions by momentum. As mechanical drives from line shafts gave way to electric motors, the mechanical throwout became unnecessary, but brakes were still lacking.

TYPES OF MECHANICAL AND ELECTRICAL BRAKES

Today both mechanical and electrical brakes are available. Both classes operate on the high-speed drive shaft and utilize the mechanical advantage of the chain of reducing gears to obtain quick-stopping action. The strictly mechanical type of brake employs a weight-actuated lever, as shown in Fig. 2, to apply the brake. Normally the lever is in the elevated position but, when the release mechanism is operated, the power to the electric drive is cut off and the brake lever is released. It happens that the brake shown in Fig. 2 is electrically held by a solenoid and that it is applied by interrupting the current through the solenoid. Mechanically held brakes are also used which employ a system of levers terminating in a hook on the brake lever for applying the brake simultaneously with the switching off of power to the motor. In either case, the motor cannot be started again without resetting the brake by hand. The electrically held brake has the advantage of remote control and is better suited to multiple-mill installations which are driven by a single motor. Further reference to Fig. 2 will show that a catch is provided to lock the brake as soon as it is once applied.

A variation of the mechanical brake employs a brake drum and band just as does the strictly mechanical type, but the braking force is applied magnetically by means of an armature and solenoid.

Mechanically actuated brakes, whether electrically or mechanically held, provide rapid and positive stoppage of mills without injury to their drives or rolls. Simple and reliable in operation and low in first cost, they are used on the majority of installations for these reasons.

Electrical braking on mills and calenders is relatively new. The three major groups in this class are known as dynamic braking, regenerative braking, and plugging.

Both dynamic and regenerative braking require that the mill drive be either a synchronous motor or a direct-current motor. This requirement often necessitates a compromise with the type of motor drive which might otherwise be chosen for the service. Dynamic braking is rapid in the early stages, but an intrinsic fault of the method is that its effectiveness drops off as the speed decreases. It involves a succession of changes in electrical connections by heavy contactors and the use of relays to give full field for effective braking. The equipment is expensive and requires specialized maintenance skill to assure reliable operation. Regenerative braking has the advantage of maintaining full braking power at all speeds and does not involve the opening and closing of heavy contacts. This method is applied chiefly on calender drives employing direct-current adjustable voltage to obtain variable speed, but it is high in first cost.

The third group, employing plugging, is applied to polyphase-induction-motor drives. This consists of changing the electrical connections to reverse the motor while running at full speed. It requires the use of control equipment to change the electrical connections, including relays to disconnect the motor as it approaches a dead stop. This method is not approved by the safety-inspection groups of some of the states for the machinery of the rubber and plastics industries.

APPLICATION OF TRIPPING DEVICES TO MACHINES

The second phase of the safety problem involves the proper arrangement of tripping mechanisms and has received a great deal of study by competent safety and design engineers. Two arrangements are shown on the calender in Fig. 3. The first is a safety bar which is usually adjustable in height. This can be operated by the head or free arm of the operator and should be placed at about shoulder level to be readily accessible and most effective. The other arrangement is a safety cable at either side of the calender in such a position that it can be operated either by a free arm or by foot. In some cases other devices which can be operated by foot have been provided.

It has also been proposed that mills be equipped with photoelectric cells and a beam of light passing from one side of the mill to the opposite side where it is focused on the photoelectric cell. Any opaque object which passes through the beam will actuate the brake mechanism and stop the mill. This form of tripping mechanism could be relied upon as definitely as any but it is considered impractical and inconvenient because of accidental stoppages while materials are being added to the mix on the mill, or at times during the ordinary manipulation of the batch on the rolls.

The third phase of this problem is perhaps the most important one at the present time. It involves the obligation of employers to insure a reasonable degree of safety to their operators in the milling and calendering of rubber and plastics. Unfortunately, it is still necessary to force some employers to install safety devices. It is also unfortunate that safety devices are not always properly maintained in effectiveness. Rigid and periodic inspection of installed safety equipment should be the practice in every room when machinery is in motion. Much remains to be accomplished in the adoption of safety codes by the various states, although precedents have been established (2, 3). Essential features of such codes are specifications governing the location of tripping bars and cables, and the statement of maximum roll-surface travel for a given mill after the safety brake is applied.

Processing of rubber and plastics is definitely hazardous. A number of the states have no safety code for their industries. It is not possible or necessary in this brief paper to go into all of the details of brake design and installation for rubber mills. Many of these have been covered elsewhere (4). However, it is appropriate that this opportunity be taken to emphasize the importance of installing and maintaining safety equipment. Huge sums of money have been spent by conscientious employers and producers of equipment to achieve the present degree of safety but constant vigilance is the price for the continuance of safety progress.

BIBLIOGRAPHY

1 "Rubber Machinery," by H. C. Pearson, published by *The India Rubber World*, New York, N. Y., 1920.

2 "Safety Code for Rubber Mills and Calenders," Bulletin No. 447 of the United States Bureau of Labor Statistics, United States Government Printing Office, Washington, D. C., June, 1927.

3 "Tentative Safety Code for Mills and Calenders," State of New Jersey, Department of Labor, Bureau of Electrical Equipment, C. George Krueger, Deputy Commissioner, November 1, 1939.

4 "Safety First and Efficiency," by J. W. Thropp, *The India Rubber World*, vol. 69, 1923, pp. 73–75.

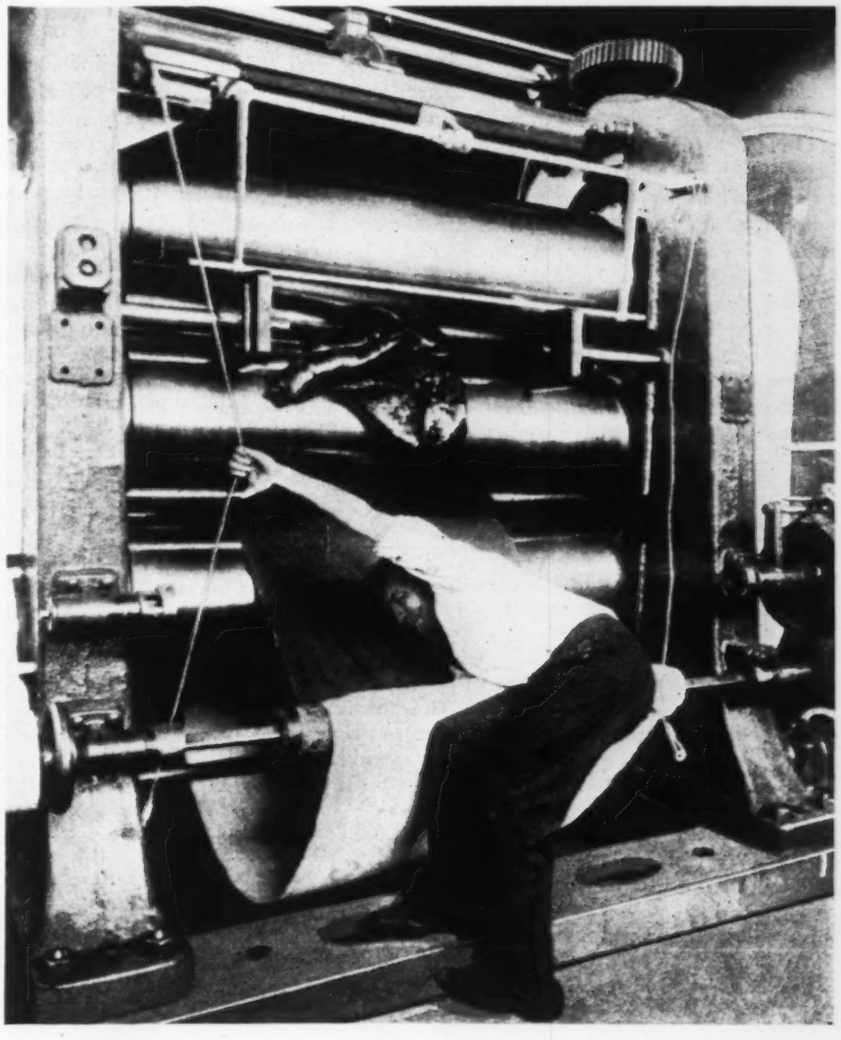


FIG. 3 WHILE STARTING A CALENDER AND FEEDING FRICTION ON TAKE-UP, OPERATOR'S RIGHT ARM BECOMES CAUGHT; HE STOPS CALENDER BY PULLING SAFETY CABLE

The ENGINEER'S RESPONSIBILITY *in* MANAGEMENT

By THURSTON H. ROSS

PROFESSOR OF MANAGEMENT
UNIVERSITY OF SOUTHERN CALIFORNIA, LOS ANGELES, CALIF.

A MAN came into the office the other day and asked for a book on management. He stated that he had just gotten a new job, and it involved his taking charge of a considerable production department. He had received his training as an engineer, which he claimed to be from a correspondence school and by hard knocks. My observation would lead me to believe that he probably had done better in the school of hard knocks than he had done in the correspondence school.

However, here was a man who professed to be an engineer, and he had been and was in competition with you men for a job of considerable responsibility. Having had a negligible training in engineering, if indeed any at all, and having apparently been so successful, I felt that his luck could not possibly hold, that he was very close to the ultimate. So I told him that I could not recommend a book on management, but suggested that he might do better in medicine because a man by the name of Osler had written a very excellent book entitled "The Practice of Medicine," that it had only about eleven hundred or fifteen hundred pages which could be digested in a relatively short time, and that it was much easier to cure the comparatively few diseases that man is heir to than it is to cope with the tens of thousands of ills in industry which must be prevented or cured by management.

Some of you may think that I may have been unduly facetious with this man who had just picked up our profession of engineering. This is not the case. I really mean to draw a parallel between medicine and management and between surgery and engineering. The essence of medicine is a correct diagnosis of what may be wrong. Treatments are prescribed, pills are given, or surgery is performed to relieve these ills. Diagnosis too is the essence of management. Many physicians fail and their patients die because of wrong diagnosis. They may instruct the surgeon to operate when no operation is justifiable. Many "managers" fail because of incorrect diagnosis. They may instruct the engineer to design, install, or operate equipment when such design, installation, and operation is not warranted. Almost anyone of good mental caliber can compound a medicine or pick up the trade of surgery and practice it successfully if he can find out what to do. The same is true of engineering. The terrific technical, economic, and theoretical engineering problems coupled with involved legal restrictions on the use of men, materials, and capital have made the field of management a terrifically complex one.

GOOD MANAGEMENT HAS BECOME ESSENTIAL TO INDUSTRY

It is unfortunate that the field of management has so long been associated with the possession of wealth. Traditionally, it is assumed that men who had capacity enough to make money could run business and industry. Such a position is easily defensible and readily demonstrable up through the first decade of this century. But great advances were made in engineering science. Procedure in financing industry became more complex; the gulf between the worker in a factory and the owner of an enterprise widened so that personality in the industry, operation of its equipment, design of its materials, and distribution of its product became functions of the organization rather than responsibilities and choices of the individuals within the enterprise. The assembly and direction of materials and forces which we call industry became the field of management even though finance, law, accounting, and even engineering, particularly the efficiency-engineering type, laid claim to it.

We do not have to go out of The American Society of Mechanical Engineers to find the pioneers and the greatest contributors to this field of management. Frederick W. Taylor, Harrington Emerson, Carl Barth, Dexter S. Kimball, L. P. Alford, and Hugo Diemer are only a few of the men who at the beginning or in more recent years have made substantial contributions to the field of management.

WHAT TO DO VS. HOW TO DO IT

Originally, the pioneers in management were interested primarily in how to do things. We are quite as much interested in this same matter today, but overshadowing it, and perhaps even dwarfing it, is the question of determination not alone of how to do things but what should be done. This means diagnosis of the problems of industry. If we can get these problems stated in proper form, we are not likely to have a great deal of difficulty solving them.

There seems to be a tendency at the present time to have surveys made to find out what should be done. This is a step in the right direction, but we should not overlook the fact that the scope of a survey is limited by the capacity of the individual making it. The present emergency has bred a substantial group of professional surveyors. They will survey your personnel problem, your industrial-relations problem, your planning procedure, your processing arrangements—anything in your plant or without it so far as that is concerned. Some of these survey experts are engineers, others accountants, still others lawyers; in fact, almost any sort of training seems to be the qualification of these expert salesmen in the survey business. I am always suspicious of the man who has a good profession and does not practice it. Therefore, I look with suspicion on many of these economic surveying parties, members of which have abandoned their stated professions to explore newer and, strange to say, in most cases less productive and less remunerative fields. Examination of several of these surveys made by highly paid, although temporarily unemployed, second guessers frequently discloses the fact that one of the principal purposes of the survey is to find a permanent job for the surveyor.

We have many industries throughout the country which, because of government beneficence or some other fortuitous circumstances in our economic situation, are notoriously mismanaged. The excuse for this lack of adequate management

Presented at a meeting of the Los Angeles Section, Los Angeles, Calif., Jan. 16, 1941, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

frequently is expressed before the mismanagement or lack of management is admitted. For example, the old stock alibi is that the industry has had to grow too fast or its product changes too rapidly to permit good management in the strict sense of the word. It seems to me where the pressure of rapid growth is so obvious, the fact of economic demand is indisputable, and certainly when such economic demand is apparent we should use every possible effort to insure good management.

MANAGEMENT TOO OFTEN PLACED IN INCOMPETENT HANDS

I do not wish to be misunderstood. I am heartily in favor of most complete investigations being made in the field of industrial management, but I insist that these surveys should be carried on by men of training and experience in management. The most efficient statistician usually is unable to go beyond statistical theory; that is, he cannot apply statistical method to industrial operations concerning which he has no intimate and practical knowledge. A cost accountant without a peculiar knowledge of the specific type of industrial operation for which he is compiling costs is entirely at sea. An eloquent public speaker, despite the excellence of his diction, would certainly not be chosen to give technical instructions to a tool or die maker, assuming that the orator had no training or experience in the field of die making. Yet in many of our industries we have the situation of fortunate financiers passing on the advisability of engineering operation; boards of directors, some of which may be holdovers from old receiverships, passing profound judgment on technical engineering operations and procedures. But if something goes wrong in the industrial-management program, it then is the manager's fault. One of the big difficulties in American industry today is that we carefully ensconce our principal motivating authorities in the deepest glass cases in the front office, but attempt to broadcast responsibility throughout the entire plant. This will not work. For the most part, material authority and responsibility should rest in the hands of a comparatively few people in the plant, but these few certainly should be specifically trained and qualified to exercise these functions.

Those interested in social reconstruction, many of whom have never had to look forward to the task of meeting a pay roll or completing a production order, have voluminously accused industry and particularly technical men in industry of attempting to lock-step human beings in a factory and of driving the human race to the status of the living dead. If the need for this defense program is genuine, management had better clear its line of these would-be messiahs in the social system and had better direct their attentions away from what some of them call lock-stepping industry. If we are in an emergency, as we are led to believe, it is imperative that we adopt a rational rather than an emotional state of mind with respect to labor relations as well as social influences generally. We are face to face with a situation where there are comparatively few people trained to do any sort of productive work and time does not permit management to adjust itself to temperamental outbursts or philosophical leanings of the workers. We who know how to do things must analyze our knowledge and reduce instructions to the simplest terms and operations to the most elementary movements. We must make use of the principle that repetition of well-designed operations will lead to proficiency of the worker. Whatever effect this repetitive operation may have on the moral, intellectual, social, or religious life of the operator is, for the time being, incidental; furthermore the ill effects of such repetitive motions are more apparent in the literature and discussions of these social "reconstructionists" than among the workers themselves. Soldiers march in step, step after step, without demoralization. The principal difference between the performance of a symphony and the bedlam of the musicians tuning up is discipline in following of note after note, measure after measure, page after page, according to a well conceived plan.

SHORTAGE OF SKILLED WORKERS A HANDICAP TO ENGINEERS

The engineer has a tremendous responsibility in management so far as these things are concerned. If he designs a new machine he must assume a strong likelihood that it will not be operated by a trained mechanic, and even at the sacrifice of many desirable adjustments and perhaps considerable flexibility he must make it foolproof. The engineer, in designing a part, assembly, or some specific product, must bear in mind that his contribution to management lies substantially in the anticipation that the product will be made by machines actually available because the machines most desirable for its fabrication may not be on the market or may be soon required for some other type of work.

We have plowed-under acres of agricultural products in an attempt at agricultural reconstruction and are conscious today of the loss which that misconceived program of agricultural reconstruction has entailed. But during the depression and in the attempt to solve the unemployment problem we have in effect plowed-under an even more important national asset—the skill of many of our mechanics. Take a skilled lathe operator away from his machine for a few months and it is likely that he will have lost much and may never recover all of that skill. But take away the belief in the assurance of livelihood which that skill presupposes and the man, his family, and friends wonder why anyone should want to acquire a skill. Because of this situation young men are only mildly interested in trades. The best one can expect of them is that they will be machine operators, and only machine operators, until they can get a softer job. It is a problem of management to disseminate all possible propaganda in favor of trade training and manual skill. We cannot achieve substantial industrial strength without it.

PRESENT EMERGENCY AFFORDS OPPORTUNITY FOR ENGINEERS

Many of us look at the personnel problem in industry in wholly an objective sense. Perhaps we would be better off today in business and industry, it might be that we would have been better off throughout the depression or perhaps the depression might not even have struck us had we paid a little bit more attention to our own status as engineers in economic society. The wealth of this country is a result of production. We have no wealth that is not produced. Even land is worthless until improvements are constructed to transport, store, convert, or otherwise utilize its products. We often speak of natural resources as being great reservoirs of wealth. They are wealth only in so far as the productive capacity of our people is able to take advantage of them.

The method and procedure of providing wealth is almost exclusively in the hands of the engineer. I do not recall a time, since the last world war at least, when the engineer as such has had any material part in the administration of that wealth. The engineer in too many cases has been the stable boy for the lawyer and the banker, and it has been his own fault. There is no profession which demands a more exacting course of training than engineering, and I am assuming that we restrict the term to professional engineering. Yet the engineer has done little to sell himself to the public. In good times he has been just a salaried man, and in bad times, he has too often been on relief. The engineer has managed himself poorly, and, largely because he has done such an inefficient job of managing himself, we find that the function of managing industry has been passed on to other professions.

This emergency gives the engineer one more opportunity, and he has had many, to find himself a place in the administra-

tion of enterprise. His battle cannot be carried on alone, but should be waged by the society to which he belongs. Instead of more members, we should find better members who can afford, if necessary, to pay more dues because their higher status places them in a higher income level. Instead of concentrating almost exclusively on how to do things, we should be paying more attention to what really should be done. The engineer could do more than plan programs in industry. He should supply the motivation for those programs. Frequently the engineer is called in only after extensive programs of operation have been laid out, and his principal function is to make the banker's promise good; had he been called in at the beginning, he could have made it much better.

Engineers have been good salesmen for everyone's program or everyone's product except their own. That is the reason we can buy engineering service so cheap and hold it in no higher regard than we do. Many feel that if an engineer can do no more with himself than he has done, he is not likely to be a trustworthy and capable administrator of the capital of an operating enterprise.

This situation may or may not change. It is up to the profession itself. Engineers can get jobs today. They can at least get into industry. This was not the case a few years ago. They can get their minds off the problem of getting some food into the pantry for tomorrow and can and should devote some of their time to the improvement of their status in industry. The particular division of activity which I recommend for their consideration is their finding a permanent and satisfactory place in the field of management.

WASTES IN INDUSTRY CHARGEABLE TO MISMANAGEMENT

I have another reason than interest in ourselves for advocating this. I was on the Hoover Committee for Simplification and Elimination of Waste back in 1926 and 1927. I was interested in seeing the causes of a good many of these wastes. Ignorance was the principal cause. Rationalizing the problem of production in 1925 and putting qualified men in charge of our producing units then might not have prevented the depression, but it would have enabled us as engineers to take a few years vacation in the early thirties instead of so many engineers going on WPA. It is my opinion that while waste in materials may have been somewhat remedied in most industries, we are wasting time, wasting effort, wasting man power, and wasting the taxpayer's money as much, if not more, today than in 1929. I charge these wastes to mismanagement in industry, and I believe that we are more wasteful here on the West Coast than in most other parts of the country. It is only because of almost unlimited supplies of materials, man power, and facilities generally that these wastes are not more apparent. They are not restricted to any size of industry, although it is my opinion that larger and older organizations generally have a better record to show than smaller ones. When one attempts to classify these wastes, he is face to face with a dilemma. Some of them arise from the fact that plants are out of balance, others because of the right man not doing the job; that is, difficulties with respect to personnel acquisition and training. In still others, particularly in small plants, we are trying to get jobs done for which we are not properly equipped.

Perhaps the biggest waste of all is red tape. It is doubtful whether the engineer can ever hope to cut red tape as rapidly as the politician manufactures it, but at least we must try.

Another waste having to do principally with personnel in executive positions is due to the fact that in some plants there seems to be a political or social administration which takes precedence over the industrial and business administration of the plant. I hear many rumors, in fact so many that I am beginning to think that they are based on a considerable foundation of fact, to the effect that if you drink cocktails with the proper crowd you get along in certain plants which we might consider to be critical industries. Such a condition prevailing seems to me to be the evidence of one of the most devastating lesions in management. It may be only a rumor, but if it is a fact, we are facing a problem far more serious than we think, because after all when administrators have the slightest inkling that their merit is measured by something else than their productivity, production in the plant becomes a secondary and inferior consideration.

PROBLEM OF A PROPER LAYOUT

One of the management problems which confronts us in growing industries is that of a proper layout which to administer. Many of our plants have been built to the specifications of architects who were neither interested in nor capable of passing judgment on layout problems likely to be experienced. I have always maintained that layout was not an architectural problem, which means that for the most part plant design is not an architectural problem. It seems to me that a plant should be built around a layout. However, this idea seems not to be a generally accepted one, and management is face to face with problems every day arising out of architectural deficiencies in industrial buildings. Too much time and effort in management and in engineering are spent in make-shift remedies for mistakes of others in industry who should have used engineers qualified in the field of management in the first place. However, buildings that are already constructed and must be operated as factories cannot easily be changed, and we must get along with them as best we can.

Many times a poorly designed plant for the type of layout which is indicated may be adjusted to current needs by carefully worked-out expedients. Sometimes we condemn the layout as a whole when we might by proper study find that only minor changes need be made to render it workable. One of the common faults of an inadequate layout is that bottlenecks occur in the production line. In some cases, work accumulating in these bottlenecks may be farmed out to other enterprises. But in many cases, bottlenecks can be substantially remedied simply by advertising them. I recall one very vicious bottleneck occurring in an enterprise which I was operating, and because of the architectural layout of the building, the pressure of immediate production demands, and the lack of availability of additional equipment, apparently nothing could be done about it. The problem was solved, however, by the rather simple expedient of letting everybody know that a bottleneck was there. I became convinced that it might be as reasonable to post the highway over which materials in process passed as it was to post the highway over which motorists passed. Therefore, I studied the layout problem from the standpoint of stoppages and difficulties. Every day we had difficulty in a certain part of the layout because of the layout itself, we hung up a flag where the trouble occurred. I will admit that when the study started, the shop looked something like the inside of a circus tent, but the flags came down. My men appreciated their significance and by pure cooperation of man power we were able to make a very poor layout adequate for temporary needs at least. This is an example of just one of the engineer's functions in management.

TOO FEW ENGINEERS IN EXECUTIVE POSITIONS

About a year ago, I saw a study of executives in a thousand large American industries; not banks, not business houses, but industries. Each one of these plants was making something that was needed in this country. All of them used a considerable amount of engineering skill and advice. In only 49 of

(*Continued on page 542*)

"THE FORGE OF VULCAN," BY JAN BRUEGHEL, CIRCA 1600
(In the Collection of the Higgins Industrial Museum, Worcester, Mass.)

The FORGE *of* VULCAN

Historical Review of the Iron Industry and the Contributions of Armorers to the Metal-Working Art

By JOHN WOODMAN HIGGINS

PRESIDENT, WORCESTER PRESSED STEEL COMPANY, WORCESTER, MASS.

THE materials of industry, science, and art are the products of nature. Prehistoric man discovered small nuggets of soft gold and copper. He may have found lumps of a hard mineral iron ore and an occasional iron meteorite, but all he could do with these was to pound up other minerals. Some volcanic or accidental fire may have fused a globule of iron from its mineral ore, but man's first iron furnace is legendary and the fact that the earth does not give us iron in its free state and that a temperature sufficient to separate iron from its natural compounds, or to fuse a meteorite, was so unusual and difficult for primitive man to produce, delayed the utilization of this element until our historical 6000-year period, after an evolutionary background of a million years.

IRON ORES ARE WIDELY DISTRIBUTED

Iron in its various natural chemical compositions is one of the most generously distributed mineral substances on earth and is perhaps the most essential to our civilization. More than half of American industry is substantially dependent upon iron. Ninety-five per cent of the world's metal output is iron and its total value exceeds that of all other metals.

Ferrous ores are found in practically every country, but the deficiency of deposits within the prewar German Empire is one reason back of the shuffling of the economic, geographic, and political history of the world today.

About one third the available known ore supply lies within the borders of the United States. Sir Walter Raleigh first recognized iron ore in North America in 1578, but he returned to England without a specimen because he was "wholly gentleman" and searching only for gold. America's first iron-smelting furnace was built in 1584 in Jamestown, but the first commercially operated furnace started in 1646 in Boston. The American Indians never produced iron or used it except as it was supplied to them by white settlers, nor did the Mound Builders, Cliff Dwellers, Incas, Mayas, Aztecs, Toltecs, or any early American peoples ever smelt their hematite hammers into iron, although Asiatic and European smiths had been doing this for 4000 years.

Sweden was the world's largest iron supply in the eighteenth century because of her rich ore which yields 65 per cent pure iron. Our ore yields 45 per cent. Our country is now mining about one half the world's output and sending much of this ore

The steel industry had its beginning in the dawn of recorded history and was broadly developed by the mediaeval armorer-smiths for weapons and body armor. The author of this paper entertained the Metals Engineering Division of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS at his plant during the Spring Meeting, Worcester, Mass., May 2, 1940, where amid his famous collection of armor, he presented the paper here printed.—EDITOR.

IN THE ANCIENT WING OF THE MUSEUM, ARMOR AND UTENSILS GOING BACK TO THE STONE AND BRONZE AGES ARE ON DISPLAY

abroad. At this rate of consumption, our own supply of commercial-grade ore is estimated to last only about 125 years and the whole world's known supply not much longer, even though the constant improvement in methods and quality alloy steels is reducing the tonnage of ore required. Such a period of time is only a flash in history. We have in reserve, however, a total of four billion tons of scrap metal, of which we use only one per cent a year and export only one tenth of one per cent.

Our fifth great grandson may be forced into the junk business, to rework the world's scrap which our tenth great grandfather started to make here in Massachusetts, soon after he landed on Plymouth Rock, unless some atom-smashing cyclotron will reduce commercially those lower-grade minerals which yield as little as 10 per cent iron. Of "potential" low-grade ores we have an abundant supply estimated at seventy billion tons in the Lake Superior district alone. This is three times the present world's known reserve of commercial ferrous ores.

Last fall the market price of scrap iron soared above that of raw pig, because Japan wanted a million tons to rework for destruction in China and not for skyscrapers and automobiles. According to the law of conservation, that iron is not lost but very little of it will ever find its way back to the market. Here is a challenge for our grandsons.

WILL ALUMINUM ALLOYS DECREASE THE NEED FOR IRON?

Will aluminum alloys come to our aid? When we were boys, aluminum was so marvelous and rare that specimens were displayed in museums and jewelers' windows. It was more costly than gold. Today aluminum is a household material; but we find that the remaining available supply of bauxite clay (aluminum oxide, $H_4Al_2O_5$) within the United States (which yields 23 per cent metallic aluminum) may not last through the next generation. We are importing bauxite now, but the world's supply should last a thousand years, and by then atom smashers may be reducing all common clays (which yield 12 per cent metallic aluminum) so why worry?

Today aircraft parts are made from aluminum alloys (No. 61ST, Al 98 per cent, Mg 1, Si 0.5, Cu 0.3, Cr 0.2) as strong and hard as iron (50,000 psi tensile strength and Brinell 95) and as light as aluminum (sp gr 2.7). On a weight basis this is nearly three times stronger than our regular low-carbon steel (S.A.E. 1010, 60,000 psi tensile strength, sp gr 7.84), or one third as heavy for practically the same strength, but ten times more costly for the same gage or strength, and only one seventh as hard as hardened steel (Brinell 600, tensile strength 350,000 psi). So steel remains to us the medium supreme for man's fullest expressions in industry and science.

WHEN AND WHERE DID MAN-MADE IRON ORIGINATE?

The search for the birthday and birthplace of man-made iron has attracted the attention of steel engineers, archaeologists, and students of history for two generations and has raised many controversies.

Brushing over the Biblical references to the Garden of Eden and to Tubal Cain, reputed to be the first "instructor of every artificer in brass and iron," as of 4000 B.C., we find only meager historical or even legendary references to iron and no specimens earlier than the third millennium before Christ, except the iron bar in the British Museum said to have been excavated from the Kephron Pyramid of 3700 B.C., and a few beads from the El Gerzeh tomb in the Valley of the Kings (4000 B.C.), which, however, have just been analyzed and identified by their high nickel content of 7 per cent as meteoric iron, with a birthplace in the heavens. Egyptian texts of 3500 B.C. refer to iron tools but reveal nothing on which we can base the history of iron.

From the third millennium B.C. we have traditions, references, and sporadic specimens of wrought iron, like a plate, a pick, and a dagger from other Egyptian pyramids; but recently this dagger has been analyzed as meteoric rather than terrestrial iron. Iron swords found in the great pyramid of Gizeh, 2900 B.C., and in the tomb of Abydoz, 2600 B.C., are exhibited in the British Museum; even these are said to be of meteoric origin.

As we merge from the Stone Age into the Bronze Age (second millennium before Christ) we find some oxidized iron objects excavated in Greece and Crete as well as in Egypt, including a bright steel dagger from Tut-ankh-Amen's tomb of 1350 B.C.; but not all of these, even Tut's knife, are yet free from suspicion of that high nickel taint of the heavens. Metallurgical researchers into the genealogies of the noble aristocracy of pure irons have swept aside the romantic traditions some archaeological biographers tried to ascribe to the Bronze Age.

The Old Testament chronicles of this period record that "iron is taken out of the earth" and seventy other references to "bars of iron" and "bows of steel." The Canaanites invaded Israel about 1400 B.C. and could not be expelled because they had "900 chariots of iron." Moses commanded an altar to be built of "whole stones over which no man hath lift up any iron," and the Philistines prohibited iron in Israel in 1000 B.C. "lest the Hebrews make themselves swords or spears." Although Moses reputedly left us exact records of the Creation and the Garden of Eden, the birthday and birthplace of man as well as of his iron is still wrapped in deep mystery.

HITTITE IRONWORKERS, 1400 B.C.

Some archaeologists claim that the Hittites (1400 B.C.) on the Black Sea were the first ironworkers to control the carbon content of steel. Exhibited in the Berlin State Museum is a broken clay tablet ascribed to the twelfth century B.C., evi-

dently a business letter from King Hattusil III, the owner and general manager of the Hittite steelworks, to his apparently impatient customer, King Rameses II. The hieroglyphics have been translated as follows:

As to the good iron about which thou has written to me: There is no good iron in my "sealed" house in Kissuwadna. It is a bad (time) to make iron, but I have written ordering them to make good iron. So far they have not finished it. When they finish it, I will send it to thee. Behold, now I am sending thee an iron dagger blade.

Here we find the characteristic, 3000-year-old sales ethics of the steel industry—the distinction in quality, the supply shortage, seasonal production delay due to an "act of God," a new promise, and an appeasement of good fellowship. But the accuracy of this translation has recently been questioned.

The royal Hittite iron mines of Asia Minor are recorded as operating 2000 B.C., but the output of the forges was restricted by the owner to a few sacred vessels and ornaments for royal presents until 1200 B.C., when the Hittite empire was destroyed and the monopoly broken. Dictatorship passed from the white hands of the kings to the sinewy hands of the village blacksmith, who became the armorer and engineer of the steel industry.

Competition developed, and other Assyrian and Mesopotamian mines and furnaces started production to meet the demands of war, all unmindful perhaps of any prior practice and different technique of Mongolian foundries 20,000 mile-years away. There was no competition there and no one has yet traced a connecting influence or knowledge. Was this the first phenomenon of coincidental invention?

For the millenium preceding the Christian Era, as if to confirm the wisdom of those pioneer paleontologists who set the beginning of the Iron Age at 1000 B.C., we find libraries replete with texts, reports, and references, and science-museum cases filled with authentic artifacts substantiating claims for dozens of iron birthdays and birthplaces. This millenium was the dawn of world trade which required the exploitation of natural resources which lay close at hand.

One of these outstanding iron finds is in the Hallstatt Cemetery in the Austrian Alps near Salzburg, dated from 900 to 400 B.C. The ferrous ores of this region had long been praised by poets and utilized by smiths. Now hundreds of forged iron weapons are being excavated from two thousand graves in Hallstatt. These slavish copies of earlier bronze weapons are perhaps the best specimens yet found of the earliest comprehensive forging of iron. They express a background of generations of ore miners, smelters, and ironsmiths.

The earliest bronze implements were fashioned after the paleolithic flint celts, and a thousand years later the earliest iron tools and knives were copied after these cast and hammered bronze weapons; but stone anvils, bronze tools, and hematite sledges with wooden hafts were utilized by the first ironsmiths.

With this intractable but rewarding iron came inventive genius and skill—and eventually came intellectual power and executive ability—after and perhaps through periodic retrogressions. With controlled fire, iron technique developed into a craft, a science, and an art.

The classical tradition of the Chalybes as the renowned iron workers of all antiquity, dated about 900 B.C., has led some authorities to accept the Caucasus Mountains on the Black Sea as the Garden of Eden of iron.

DURA-EUROPOS EXCAVATIONS SHOW REMARKABLE IRON WORK

One of the richest and best authenticated finds of man-made iron and steel of this period—unmistakably of local armorers' production and contemporary use in city life—was discovered by accident and recovered recently by the Yale University archeological expedition while excavating the site of Dura-Europos in Syria.

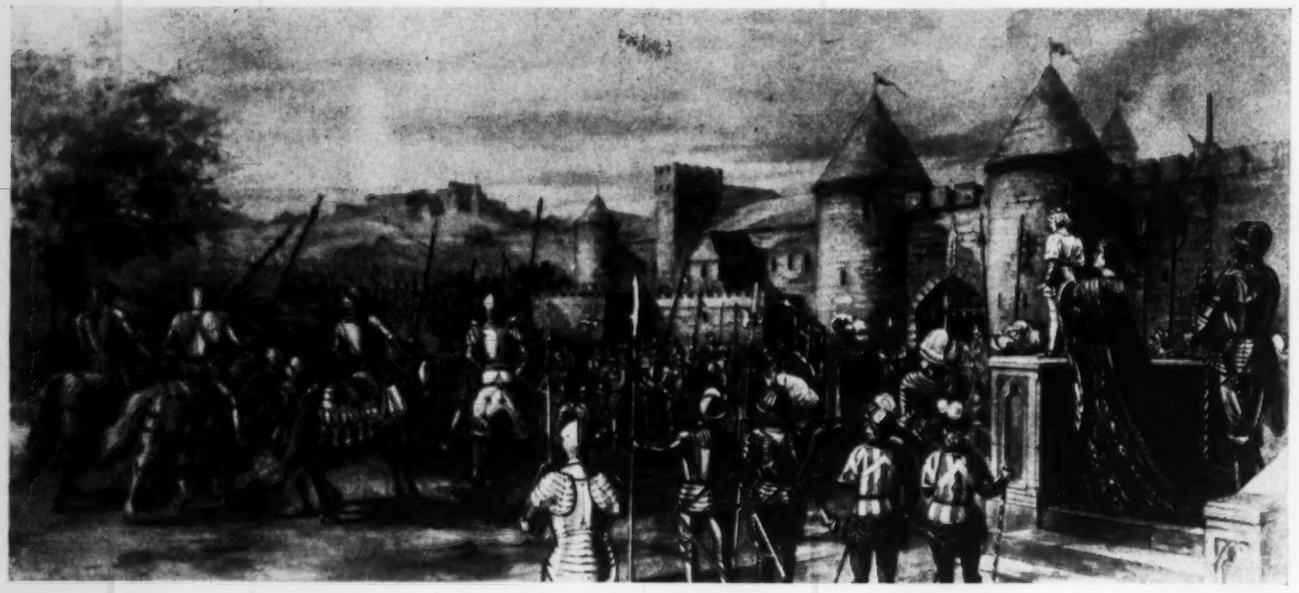
CAREFULLY SELECTED EXAMPLES OF CRAFTSMANSHIP OF THE PAST SERVE AS INSPIRATION FOR MODERN ARTIFICERS IN SHEET METAL

History records that Alexander the Great in 320 B.C. allotted homesteads in Asia Minor to three of his victorious generals. To Seleucus he assigned Dura-Europos, a stronghold on a high bluff overlooking the Euphrates River, south of Nineveh and east of Damascus, strategically situated on the important Mesopotamian caravan route from the Black Sea to the Persian Gulf. This flourishing city was accessible to the Hallstatt and the Hittite ore mines and forges.

For five centuries this Dura fortress was held by the Romans, when the Sassanians captured and burned it in 256 A.D. through a clever sapping tunnel that would have done credit to present-day engineers. Apparently these ruins were then deserted and forgotten for 18 centuries, while the warm desert sands spread a protective mantle over the entire location. British soldiers digging trenches on the banks of the Euphrates River after the World War struck the stone walls of a church beautifully decorated with Biblical scenes in typical early Christian art. This find rather upset the long-faced ecclesiastical archaeologists who had declared that the early Christians never decorated their churches.

Yale University, cooperating with the French Academy of Science, organized an expedition, secured permission of the Syrian Government, and in 1929 started to dig. Today a gallery of the Yale Museum of Fine Arts is filled with marvelous mural frescoes, textiles, parchments, decorated shields, and bronze implements of exquisite workmanship. The iron objects have been loaned for study and exhibition to the industrial museum of ancient and modern steel products of the Worcester Pressed Steel Company.

While the metal and the craft-technique as well as the design of these 2000-year-old specimens favor the Middle Ages, they



GROUP OF PARADE ARMOR

register a stage of an art already advanced many generations. Not until the seventeenth century when blast furnaces and rolling mills began producing "steel" in quantities do we find such abundance of this valuable metal applied to protective armament, for horse as well as for man, and to large spikes, swords, lamps, pipes, horseshoes, bits, caltrops, chains, and builders' hardware. No earlier than the eighth century have such iron objects been ascribed by historians. Therefore we must go back to earliest contemporary documents, like the bas-reliefs at Persepolis, the altar of Domitus Ahenobarfus, and the first-century bronze columns of Trajan and Marcus Aurelius in Rome to see Sarmatian warriors armed with such weapons and clothed in chain-mail and scale armor from head to foot. Now we no longer surmise that these first-century armors were mere leather or bronze. We assert that they were iron "fish scale" mail like the brigandines illustrated on the eleventh-century Bayeux tapestry and like the thirteenth-century iron specimens exhibited in armor museums. We now marvel at the skill of these Sassanian blacksmiths rather than that of William the Conqueror's Norman armorers nine centuries later. Dura for the first time authenticates real war arms and armor for Caesar's captains in New Testament times. The Greeks may retain their Corinthian bronze swords as masterpieces of acanthus-leaf design, but this Roman forged iron armor was far superior to bronze. We must rewrite the first chapters of our histories of armor and iron craftsmanship and steel metallurgy.

The Dura armorers forged iron plates, swords, spear and quarrel heads with dexterity and confidence as well as knowledge of the metal, utilizing wrought-iron anvils, hardened hammers, swages, punches, shears, and tongs, with charcoal fire and forced air blast. The design and workmanship of their line of commercial hardware suffer nothing when compared with familiar fifteenth-century examples.

One-piece iron quarrel heads were forged with socketed shanks to receive wood hafts. No effort was made to close or weld the seam in the sockets. The split opening allowed the pointed wood shaft to be driven in securely without pinning. The square heads were well shaped for service but were left roughly forged; an efficient commercial technique for war weapons to be used but once; evident conservation of labor in mass production. The perfectly preserved wood shafts of these short, heavy quarrels were roughly whittled and fitted with three leather "feathers," evidencing the use of crossbows which are supposed to have been first introduced in the eleventh century to replace the earlier long bows for long arrows. Two iron quarrels had pierced holes through a bronze scale-plate armor, but no crossbows or ballista were found for these quarrels. Graffito wall drawings illustrated curved long bows and arrows of the familiar Oriental type and a number of long wooden arrows were found, but why no bows of any type were found within this fortified city we can only imagine.

The iron plates of the horse armor are hammered uniformly thin, annealed with a blue scale, but have no indication of burning, work hardening, brittleness, lamination, or rusting. File marks still show on the face of the plates as though these were polished but yesterday. Three of these full horse panoplies were found, two of bronze but only one of iron. Fortunately, this unique iron armor came to America. It comprises 1400 overlapping plates (about $1^3/_4$ in. $\times$ $2^1/_4$ in. $\times$ $^1/_{32}$ in. thick), each punched with eight holes, fastened together in rows by wire staples, and sewed with rawhide thongs to a woven jute blanket (about 46 in. $\times$ 64 in). The wire staples are of iron or copper, used indiscriminately, all sheared or forged—not die-drawn. The entire panoply is hemmed with soft tanned leather, with back strips and end flaps of heavy rawhide, still strong and marvelously well preserved.

Some larger (2 in. $\times$ 3 in.) loose iron plates of similar shape were also recovered, evidently belonging to a brigandine.

There was also discovered a remarkable iron chain-mail cuirass, now congealed into one solid mass but not disintegrated, resembling a typical fifteenth-century coat of chain mail with close riveted link mesh. This was found just where its owner dropped it on the wood floor of the guard tower, "petrified" during its twenty-century wait for us. How kindly were these dry desert sands that drifted into this deserted city and how fortunate that scanty annual rainfall of only three inches. This specimen is unique. Another rusty iron cuirass was found still faithfully protecting the skeleton of its brave hero, who was caught in the tunnel under the tower.

Some of the small iron dart and arrow heads with sharp barbs and tangs are beautifully fashioned for sport, while horseshoes and nails are crudely forged with rugged fitness. Evidently, Dura labor was valued above material. Both socketed and tanged heads were found; both types as classified

in our present-day tool catalogs. The tools were also made by and for practical mechanics, antedating our earliest records by nine centuries. We have found welded rings but have not yet discovered examples of casehardening, brazing, tinning, soldering, or casting of iron in Dura-Europos.

The largest find of such early iron is the recent excavation of the Assyrian castle of Sargon II of 720 B.C. at Khorsabad, comprising a great hoard of iron, including 176 lb of billets, 1 to 2 ft long, 9 to 44 lb each, and a great variety of finished iron implements, chains, horse bits, etc., aggregating 200 tons in weight.

From the Hallstatt (900–400 B.C.) and La Tene (500 B.C. to 100 A.D.) cultures of Europe (France, La Marne, Champagne, Coblenz, Neuchâtel, Germany, Austria, Hungary, Spain, Northern Italy, the Balkans, Transylvania, Asia Minor, including the Carpathian Mountains) in this pre-Christian period are many finds of wrought iron (weapons, knives, axes, tools, hardened files, chains, bridle bits, wheel tires, and other chariot fittings) but no cast iron.

Historians and archaeologists are not mineralogists and metallurgists, and vice versa, so we may expect to find erroneous and conflicting conclusions when each specialist independently tackles the story of iron which is so interrelated with history, archaeology, mineralogy, and metallurgy and industry round the world. All of us should confer in one round-table clinic.

EARLY EXAMPLES OF CASTING OF IRON

Certain iron-ore oxides when heated slowly with charcoal fuel to a dull red (1000 F) will reduce to soft, ductile, wrought iron practically free from carbon. The slag will draw off or hammer out so that any blacksmith can meet almost every demand; but this same iron cannot be melted at less than a white heat (2800 F) which requires coal or coke fuel and a continuous strong blast of hot air for excess oxygen, most difficult for primitive fire builders to produce. But if this iron is heated to a yellow color (2000 F) it will absorb 1 to 2 per cent carbon (20 to 40 lb C per ton) and become tough strong steel capable of being hardened into tools for cutting other materials. If this heat is continued at 2200 F, the steel will absorb as much as 3 to 6 per cent carbon (60 to 120 lb C per ton), fuse, and flow readily into molds producing gray-iron castings of low tensile strength (18,000 psi) but exacting the expenditure of very little time and labor. This cast iron may then be remelted at this lower temperature (2200 F) in a controlled furnace and the cycle reversed to reduce the carbon, so that a refined, hard tool steel (20 lb C per ton) or strong, soft steel (10 lb C per ton) or even a pure, soft, carbon-free iron is obtained. Every ton of ore smelted requires three tons of other minerals and fuel to yield an 800-lb ingot of iron. To discover and control these and other fascinating techniques of iron in relation to its 92 companion elements required forty centuries of experimentation.

Herodotus (480 B.C.), the "Father of History," described iron used in building pyramids 3000 B.C. Pausanias, the second-century writer, traveler, and archaeologist, recorded that Theodorus, the Greek sculptor, invented and cast iron statues in Syria in 600 B.C. Theophilus in 840 A.D. and Georgius Agricola in 1550 wrote their well-known treatises on cast iron, wrought iron, and steel; but some of our modern writers still declare that cast iron was first invented in Europe in the fourteenth century, A.D., overlooking the undisputed evidence from Asia where Chinese graves have yielded numerous dated and fully authenticated gray-iron castings of the Han Dynasty (206 B.C.–220 A.D.) and some from the Chou Dynasty (250 to 1123 B.C.) as well as wrought-iron and steel utensils and weapons. The Field Museum has a Chinese cast-iron stove, declared to have been made in 513 B.C.; and cast-iron pans for evaporating salt were made in China in 200 B.C. under a government monopoly.

Mongolia abounds in rich silica phosphorus (5–7 per cent) ferrous ore which yields fused carbon iron at the low temperature of 1800 F, readily obtainable with Chinese coal and hand bellows. This is 200 F below the fusing point of copper and 300 to 400 F under the temperature required to fuse European irons. European blast furnaces had to reach 3000 F to pour their cast iron. Their iron sintering temperature is 1900 F. Undoubtedly, the Chinese were the first to pour cast iron on any commercial scale. They learned to cast bronze in crucibles centuries earlier; so did the Europeans, but apparently the Europeans did not try crucibles for iron. Iron was more difficult to control than bronze.

The largest iron cored casting ever made still stands in Ts'ang-chou, not far from Tientsin, where it was cast and dated

GIANT PRESSES OF TODAY DO IN SECONDS WORK THAT REQUIRED WEEKS FOR THE METAL WORKER OF CENTURIES AGO

in 953 A.D. It is 18 ft × 20 ft × 4 ft and weighs perhaps a hundred tons. The earliest European iron castings exhibited are assigned to 1340 A.D.

But after the application about 1325 of Chinese gunpowder to European firearms, especially to large mortars, the demand for cannon and cannon balls stimulated the founding of cast iron. What an improvement these were over wood staves and bronze castings or forged and bored iron barrels, and particularly, over rounded stones for projectiles!

Iron was known in India at an early date and probably was fused and cast more than a millennium before Christ. The Iron Pillar of Delhi, said to have been cast 912 B.C., is now designated wrought iron (0.10 per cent carbon) welded from forged slabs. It is 22 ft above ground and 22 ft below ground and weighs about 19 tons.

ARMORERS ORIGINATED THE IRON INDUSTRY

Herodotus records that Xerxes' legions (460 B.C.) carried bows of cane and arrows pointed with iron and an early medical chronicle describes one hundred iron surgical instruments for delicate operations; but probably the earliest authentic iron specimens now preserved are the third-century weapons recovered from Buddha Goya.

Plutarch reports that Rome had its guild of ironsmiths in 700 B.C. and that the Roman dictator Camillus, about 400 B.C., commanded his armorers to produce superior steel armor and tempered weapons for his soldiers. Their swords pierced the shields of the barbarians whose weapons, bending double against the Roman armor, were slaughtered and defeated.

We accord high credit to a sixteenth-century Flemish painter for recognizing and cleverly recording for all time the historical truth which we modern steelmakers overlook, namely that the armorers were the pioneers, the captains of our industry, the inventors, designers, and forgers of all iron implements including offensive and defensive weapons, up to the seventeenth century. They were the sole iron prospectors, ore miners, smelters, and ironsmiths. These early armorers were master craftsmen and master artists who served their generations until modern furnaces and rolling mills ushered in our present steel age of mass production.

In the year 1500 Leonardo da Vinci, the master artist, invented and designed a rolling mill and used it to make sheet lead. Leonardo was an engineer with ingenuity and imagination as well as art coordination. Before his time all metals were worked by hammering. Thirty years later (1530) Hesse built a mill for rolling steel hot, but the armorers kept on hammering out their sheet steel for another hundred years—a process which embedded the black slag in the metal and accounted for the characteristic mottled effect of genuine old armor.

"THE FORGE OF VULCAN"

Jan Brueghel, born in 1568 to a Flanders family of art painters, father, brother, nephew, and son, acclaimed to this day among the world's art masters, must also have been a mechanical engineer, for in his great painting "The Forge of Vulcan" he illustrated hundreds of different workshop implements and tools in action, without an error or misapplication. This Brueghel "the Elder" (1568–1625), known as "Velvet Brueghel" because he dressed in velvet, painted in allegorical style the five senses and the four elements. On this panel he illustrated "Fire," under the control of Vulcan, for the production of steel. Vulcan's helpers are mining iron ore in the distance, smelting and casting it into cannon and balls, refining and forging it under a water-driven trip hammer, and fashioning it into useful and ornamental articles, decorated by etching, polishing, embossing, gilding, and damascening. Vulcan (Hephaestus, the son of Zeus), master craftsman of Olympus, the Greek god of smiths and the Roman god of fire, Volcano, is represented accompanied by Venus and Cupid, symbolizing beauty and love. As has been truly said, "Most of our arts and sciences were invented for love's sake." Even machines may be loved into beauty, for love craves beauty. Because the admirable qualities of machines are both functional and appropriate, they should be judged by those who know machines or at least by those who appreciate their service and product. A machine is not a surrealistic abstract. Trained art critics may learn to recognize art qualifications in machines and such products of master engineers. Good art like good taste is an empirical rather than an absolute criterion and changes with each judge's environment, experience, and training.

The early armor smiths had their own patron saints, Dunstan and Eloy, as illustrated in medieval sculpture and painting. Saint Dunstan, who lived and forged iron about 1000 A.D. and whose anvils, hammers, tongs, and other tools, differing little from present-day blacksmith's tools, are still preserved, is recorded in doggerel:

> St. Dunstan, so the story goes,
> Once pulled the devil by the nose
> With red-hot tongs, which made him roar,
> So he was heard three miles or more.

To St. Eloy, a horse possessed of the devil was brought to be shod. St. Eloy cut off the horse's leg, nailed on the shoe, and then miraculously replaced the leg on the horse, as readily as modern metallurgists perform "miracles" with stainless steel.

Vulcan dwelt in his forge shop in the heart of the volcano said to be "the source of all wealth and happiness," where the glowing heat kept his metals in fusion for his anvil. Here he forged thunderbolts for Jupiter, arrows for Apollo, steel armor and impenetrable shields for Achilles, and swords for Hercules. Cyclops was his "striker."

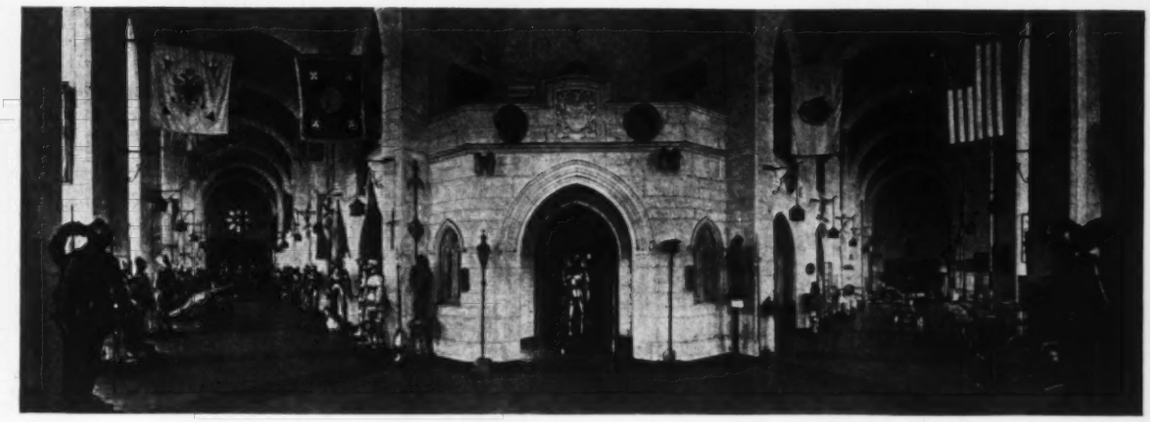
Many renaissance painters recognized the art service of these master armorers, for hundreds of times they painted this subject, "Venus at the Forge of Vulcan," and scores of these paintings are still preserved in the foremost art galleries of the world as accredited masterpieces.

MEDIEVAL ARMORERS CONTRIBUTED TO DEVELOPMENT OF STEEL INDUSTRY

A suit of medieval armor presents a complete history of the steel industry down to our day.

From microscopic, spectroscopic, and chemical analyses and from physical tests of specimens of early armor, we find that after all, there is little that is new in the steel industry. The armorers produced iron alloys and many types of steel structure 4000 years ago which we now classify by technical names, from their primitive charcoal furnaces, although they did not know just why or what or when. They did not realize that they had ninety-two different elements at their service; but they learned by patient trial and test that certain Swedish iron ore smelted with certain fuels in certain furnaces produced specific results which they wanted to duplicate. Today we discover why and we control those factors—freed from superstitions and prejudices.

The Milanese master armorer, Andrea Missaglia, in 1450 insisted that his new order for steel battle armor for Emperor Charles V must start in a certain Spanish ore mine, rather than in his native Italian bog. Today we find that this Gothic breastplate carried a 3 per cent natural alloy of manganese, with traces of chromium and nickel. Nowadays we cold-press bulletproof steel helmets from $^1/_{32}$-in., rolled, 12 per cent manganese steel (130,000 psi tensile strength) and they withstand the direct impact of 45-caliber army pistol bullets at ten feet. Only one out of every fifty helmets is tested and these indented



THE COLLECTION OF THE JOHN WOODMAN HIGGINS ARMORY, WORCESTER, MASS.

helmets are issued with the others. The recruits who get these proof-dented helmets feel a particular security.

Philip Negroli, the Michelangelo of armorers, tested his sixteenth-century breastplates by using home-made black powder and a round lead ball, before this royal patron would accept the armor. Some breastplates were then engraved with acanthus leaves radiating from this prized proof mark; but the best early armor carried no engraving, etching, damascening, or embossing to catch glancing weapon thrusts. Only the late parade armor was ornamented and gilded by the goldsmiths, and then only after such vast improvements in powder and projectiles as enabled the musket to prevail in that ever-recurring struggle between offensive and defensive weapons, which carries on to this day, despite the acknowledged supremacy of modern arms and ammunition. More armor was used in the World War than in any prior war—more guns capable of piercing all armor. A modern battleship is a suit of armor for fourteen hundred men and carries guns that will destroy any armor.

Gothic armor, beautifully designed, streamlined with pointed toes and slender waist of womanly grace, originated at the forge of the Missaglias of Milan in the fourteenth and fifteenth centuries, and protected crusading knights from axe, lance, and crossbow bolts, while the ingenious articulated armor plates facilitated freedom for offensive fighting.

This ancient family of art craftsmen was honored, lived in princely splendor, freed from all taxes, and was presented with the royal iron mines and furnaces at Canzo. Even fragments of this Gothic armor are sought by fine-arts museums for exhibition with other masterpieces of sculpture and painting.

Very little original early armor is preserved to this day, but such contemporary paintings as St. Michael by Perugino and St. George by Donatello remain as authentic drawings and have been reproduced by later armorers.

Edward IV for his Calais Invasion in 1475 ordered 1500 full suits of steel armor for his cavalrymen and horses, and 15,000 half suits for his archers. Milanese armorers outfitted an army of 6000 infantry in short order. A Venetian arsenal stored arms for 800,000 combatants. This demanded mass production, and those English armies were practically invulnerable for that generation. Froissart reported that the great clatter of the armorers' hammers and anvils at the battle of Rosebreque exceeded the noise of the battle.

The Colman family of Augsburg was the popular court armorer of the sixteenth century and tailored steel suits for Emperor Maximilian. These armorers prospered and were able to lend pecuniary assistance to the ever-needy Maximilian, who also kept his tailor waiting for his pay. But later the House of Fugger paid Colman 4000 florins for a steel armor which gave such satisfaction that a further sum was added as a present.

Henry II of France forged his own armor in his own atelier. Henry VIII, Charles V, and Maximilian I were all enthusiastic users and collectors of steel armor. Their interests were expressed in visits, jousting tournaments, and gifts of armor. Henry VIII imported German armorers and set up his forge at Greenwich Arsenal which developed the well-known English type of armor. Maximilian I developed the efficient and beautiful type of armor that bears his name to this day, ribbed for strength and light of weight, like our corrugated sheet roofing. Maximilian himself fought more than 2000 tournaments in full plate armor. He published a book describing how to make 30 breastplates and 30 backplates at one time.

Armor was an investment for family use, like a castle, and represented nearly the same economic expenditure and achievement. It was a work of art which not only hung on the castle walls for ornament but was worn at court functions, at sport tournaments, and in battle to preserve the life of its owner. Its extravagant importance was reflected by the sumptuous splendor of that pageant in 1520 when Henry VIII and Francis I met on the Field of the Cloth of Gold with their thousands of knights in full rich parade mail, their horses barded and caparisoned for the tournament.

Armor was designed and engraved by master sculptors and painters whose names are associated with our history of art, such as Donatello, Leonardo, Michelangelo, Raphael, Dürer, Burgmair, Holbein, Verrochio, and Cellini, and forged by master armorers like Missaglia, Negroli, Peffenhauser, Campi, Camelio, Colman, Piccinino, and Zuloaga, who were accorded honors at court ranking with the painters and sculptors of their day. Serafino di Brescia, armorer for Francis I, was received at court with Titian; Albrecht Dürer, the mechanical draftsman, and Seusenhofer, the helmsmith, were intimate companions of Emperor Maximilian.

Dr. Bashford Dean, late curator of armor at the Metropolitan Museum of Art, declared that today a complete authentic suit of early armor is a hundred thousand times more rare than master paintings or sculptures, as in its day it was more costly and highly prized.

Rembrandt loved armor and collected fine examples in his own studio. Frequently he dressed his models in odd pieces, combining, for example, a sixteenth-century cabasset with a fifteenth-century French cuirass and a seventeenth-century pikeman's gorget—a vulnerable disjunction. His father, judging by the expression in his portrait, was blissful in his ignorance as he grasped his antique Chinese sword; but his youthful "Warrior" looks "scared to death" as he buckles on his Gothic breastplate over Cromwellian pauldrons, leaving his arms ex-

posed, to enter the lists for mortal combat with an English hunting knife and a visorless helmet. Of course, Rembrandt's portraits live forever, but portraits by Raphael, Perugino, and Giovanni Bellini are documents of authentic fourteenth-century armor, even as painted on soldiers at "The Resurrection" fourteen hundred years before such armor was invented. No wonder we prize the few existing authentic examples of early Gothic steel armor while forgeries and eighteenth- and nineteenth-century armor are a drug on the market.

The aiguillettes on our soldiers' uniforms are said to be an evolutionary remnant of the cords on the knight's quilted undercoat used to tie on his armor. The military salute, with palm turned outward, and the gentlemanly custom of raising the hat on meeting a lady, came down to us from the Golden Age of Armor when the closed helmet was raised for the necessity of identification.

The first steel engravings were coats-of-arms chiseled on armor for identification and the first etchings for printing purposes were said to have been produced by Daniel Hopfer, a sixteenth-century armorer and engraver. Damascening and fire gilding were also invented at the armorer's forge. The Swiss armorers were the first clockmakers. Their craftsmanship and inventive genius established a tradition of beauty in mechanisms that spread over the borders of that little republic.

How paradoxical that Spain, which then had the best ore, produced the least armor, but today retains in Madrid the world's largest and finest collection of armor, including twenty of Charles V's suits and one for his favorite hound, and that Italy, which has no good iron ore, produced the world's finest armor and today has very few important specimens.

The clever Japanese, light of weight and small of stature, never made cumbersome armor heavy enough to withstand direct hits. Their helmets were grotesque for psychological effect and their defense was light to facilitate jiu-jitsu activity. They designed to dodge the missiles and to wield their offensive weapons effectively before their enemy found time to strike.

How significant that the medieval Japanese sword is still the world's most efficient cutting weapon. Their controlled cementation hardening process is today perhaps the only "lost art" in metallurgy; and despite the traditional Toledo blade and the Damascus sword of "watered steel," the Japanese sword with its "glass hard" (Brinell 650, Rockwell 65, scleroscope 88) edge and its tough back (Brinell 200, Rockwell 20, scleroscope 30) still stands supreme. The classic age of Japanese swordsmithing dates from the fourteenth century with Akihio to Hidekuni, master of the Olsuki School in the nineteenth century, the end of feudal rule in Japan. The sword, formerly the companion of the fighting warriors, became the formal and ornate relic of the scholarly samurai, worn at court ceremonials and preserved as a badge of family distinction and honorable ancestry.

But sixty years ago the Japanese government forbade the wearing of swords on the street, thus terminating this picturesque national custom of carrying the proper sword and dagger, equipped with the guards decreed for each season's ceremonial function. Every samurai was equipped with scores of these artistic iron tsubas, which today gladden the hearts of collectors. The unique art designs and craftsmanship of these jewels are outstanding and their classification fills many volumes. If these beautiful sword furnishings were as rare as Toledo blades instead of as common as costume jewelry, their market value would rise a hundredfold; but at present market prices, the eighteenth-century artists who designed and wrought these steel medallions would have to subsist on two pence a day for their work.

All this was sportsmanship, chivalry, and warfare combined with industry and art, when knighthood was in flower and international honor prevailed. Into that Golden Age of Armor came machinery, designed to emulate and function like the human body, expressing symmetry and appropriate beauty, adapted to available materials and fulfilling every requirement—Beauty and the Beast—both qualifications essential to life—the aesthetic and the dynamic—apparent ugliness loved into beauty.

"See the march of history,
Strewn with cast-off finery,
And the way of common things,
Cluttered with the pomp of kings."

THE PRESSED-STEEL INDUSTRY

By CARTER C. HIGGINS

WORCESTER PRESSED STEEL COMPANY, WORCESTER, MASS.

PRESSED steel is important to many industries. Its development parallels the growth of the mass-production idea, beginning in the middle of the last century. Its use is dependent on mass production, and likewise many mass-production benefits are dependent on pressed metal. Back in 1896, Oberlin Smith pointed out that pressed metal was in our cradles, our wedding rings, and finally our coffins.

The story of pressed metal begins about 700 B.C. when pairs of dies for coins were first used. These earliest dies were struck with hammers to impress their forms, but later water wheels and steam supplied power for more intricate trip and drop hammers used in forging glowing metal.

The first record of formed sheet metal of which we have any knowledge was De Vere's patent in France, granted in 1796 to cover a rough press. In 1827, a French patent was taken out on a cartridge shell made from sheet copper. Most of these early developments, however, dealt with stamping heated metal.

By 1833 Horace Whitney, working on Main Street, Dover, New Hampshire, was making tinware, using tools and dies instead of hand craftsmanship. In 1857 his firm became the Dover Stamping Company and moved to Boston where they made large numbers of tin cups, knives, and canteens for the Union Army during the war. Their first double-acting press was bought in 1880 and was believed to be the second such press used in America. The plans were imported from France.

In 1868, J. H. Cole, of Millbury, Mass., patented the punch-and-die method of cold-drawing seamless cups and ferrules from sheet metal. He shortly started manufacturing cane ferrules at the corner of Union and Foster Streets in Worcester. At this same time the firm of Higgins & Marchand Company was organized in Philadelphia to exploit a wooden press brought over by French workmen. On this press, wash-basin

Contributed by the Metals Engineering Division and presented at the Spring Meeting, Worcester, Mass., May 1 to 3, 1940, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

tops were drawn from a 14-in. blank, cammed by 3000-pound weights, placed on the platen of the press. Although press structure was kept very secret in these early days, there was a tremendous interest shown, and many people tried to steal plans to make their own presses.

Cole was bought out in 1871, and the new management added knife ferrules to their products. In nine years, their gross sales were $133,000, sold at a net profit of $78,000. Needless to say, those days are gone.

In 1883 two Worcester concerns were formed to produce stampings. One was J. Fred Wilson Company (now the Worcester Stamped Metal Company), makers of nuts, bolts, washers, and later piano bars. The other was the Worcester Ferrule Company, organized by John Bennett and two partners, replacing the cane-ferrule plant already mentioned. This company, which at one time had 60 presses, was bought by Milton P. Higgins, a Worcester Tech engineer, and incorporated in 1904 as the Worcester Pressed Steel Company. Already most of present designs had been established, although the modern hydraulic and multiple-plunger presses were later developments.

The early pressed-steel industry found a tremendous market in the bicycle field, where the concept of mass production was taking hold. In twenty years, the "safety's" weight was reduced from 40 to 22 lb and its price from $150 to $45. Tubes, seat clusters, heads, hanger brackets, ball cups, rings, and reinforcements were made cold in presses. These parts were so strikingly successful that the earliest automobiles were built with similar tubular frames. With continuing development in other lines, there was a tremendous growth in the pressed-metal market in the decade before the War. Stampings replaced castings and forgings everywhere, also creating new uses of their own.

The Great War brought about a pooling of stamping knowledge. Engineers from the great electrical-equipment companies visited our Worcester plant to study production methods. The largest stamping users were hustled into producing cartridge cases and helmets.

When the "tumult and the shouting died," the greatest stamping market of all time appeared in the automobile industry. With 90 per cent of an automobile being made on presses, the auto manufacturers soon found it worth their while to install their own press shops. Many New England mechanics went West, taking their skill with them, to this tremendous industry. Foster and Catchings estimate that the productivity of labor in the automobile industry increased 300 per cent in ten years before 1925.

New straight-line handling methods for mass production and specialized machinery, like A. O. Smith's in Milwaukee, led to new low costs. The center of the pressed-steel industry moved West, a movement hurried by the end of special freight rates on cars returning empty from the seaboard. Enormous presses began to be used, and the whole science of pressing was tremendously developed.

Many of the older jobbers were beaten at their own game and could only compete where light goods of the highest quality were required. Since this time, the pressed-metal industry has been highly competitive. There is a natural limit to stamping markets, not only because of freight, but also because of delivery and the advisability of consultation on special problems. With their rather small units, jobbers faced stiff competition from still smaller units, and from the rapidly developing specialty producers.

Taking their cue from the automobile makers, the refrigerator and electrical-equipment producers set up their own plants, too, letting out to jobbers only such short-run parts as did not justify special equipment.

As the great depression swept the country, many of the older stamping jobbers developed and marketed specialty products of their own, such as hardware or roller skates. Set up with automatic machinery, whole plants were devoted to producing kitchenware, cans, small-arms cartridges, eyelets, and the like at low prices. The once compact stamping industry was shattered a thousand different ways like water.

PROPELLER DOME

(A pressed-steel product designed to replace a forging, made from 22-in. aluminum alloy disk, 0.450 thick.)

Stamping layouts are part of the automobile, typewriter, radio, refrigerator, electrical-equipment, and other industries. They are even part of the great steel companies, set up to sell goods by the ton and find outlets for raw materials. The old jobbing plants tightened their belts and carried on, in part at least, producing quality stampings in small numbers, difficult jobs which they could put in production through experimenting without benefit of laboratory theory, and bidding on government business. As competition was especially fierce on the cost of punches and dies, new low-cost forms were designed and built of rubber, wood, and laminated metal.

It is clear that the pressed-metal industry has seen its period of greatest growth. It faces new competition from die castings and plastics, and powder metallurgy looms in the future. Die castings and plastics are considerably less strong than stampings and more expensive per operation to produce, but when a stamping involves many additional operations, especially when machining is required, the other products can be made more cheaply. For both, die costs are higher than for stampings, and scrap loss is practically eliminated. Plastics have had a real appearance advantage in the past, although recent developments in metal finishing are minimizing this.

The use of stampings is still increasing. The newer materials have created new markets for themselves. The airplane manufacturers are beginning to go into mass production, requiring quality work, in quantities insufficient to justify their purchasing complete press equipment. The strength, impact resistance, and low cost of stamped metal remain outstanding, and we can look forward for many years to continued opportunity for the branches of the pressed-metal industry to supply the public with quality goods at low prices.

The CHROME-HARDENING *of* CYLINDER BORES

By H. VAN der HORST

VAN der HORST CORPORATION OF AMERICA, OLEAN, N. Y.

THE purpose of chrome-hardening cylinders is to bring about a reduction in the wear of cylinders, piston rings, and piston-ring grooves. This paper reviews the ways in which the application of chromium metal on the cylinder bore affects lubrication and choice of fuel. It further deals with the method of application, that is, proper bonding to the base material and the properties of chromium metal as they are good or bad for this purpose.

Wear of some of the most important parts of the engine, such as cylinders, rings, crankshafts, and ring grooves, has been a topic of keen interest to many engineers, particularly when the output of engines of a certain size and weight is stepped up from time to time. The effect of wear in two-stroke-cycle Diesel engines is of a more serious nature than in the four-stroke-cycle engine, and consequently a comparatively small amount of wear in the former may cause trouble. The reasons may be found in the increased heat flow and in the totally different lubricating conditions, because there is no lubricating stroke between the firing strokes.

The causes of cylinder wear have been the subject of many disputes, and considerable research work has been done to determine how much corrosion, abrasive matter, lubrication conditions, overloading the engine, idling the engine, bad combustion, overcooling, overheating, the choice of fuel, of lubricating oil, engine design, and other factors cause wear, and to what extent such factors do so. Some of the possibilities mentioned only lead up to others; overcooling will lead to corrosion, poor combustion to both corrosion and carbonization. Some experienced engineers assert that corrosion is the only factor of wear. But in such cases, what is to be said of engines that run under conditions where sand dust or other dust can hardly be removed by filtering? Certainly such engines wear very badly, and one would assume that such wear is of an abrasive character.

Suspended matter, in the fuel or in the air, such as sand or dirt of any kind, naturally affects the wear on cylinders. Thus careful filtering of the fuel is extremely important in Diesel engines to prevent trouble with the pumps; but effective filters will take care of this difficulty. Under certain conditions, especially when the engines operate in dust-laden air, filtering the air becomes necessary.

Another factor that can affect wear is suspended water, particularly salt water, if as much as 1 to 5 per cent is present. Water can be taken in either by the air or the fuel; but under the usual specifications for fuel, the amount of water is too small to influence wear, especially in comparison with the amount of water which is taken in with air and generated by combustion. However, water is more likely to be introduced when water-cooled pistons are used because then there is the possibility of leakage. The action of suspended water on the cylinders must be considered as corrosive.

The sulphur content of fuel does not become an important factor in wear until it reaches 1 per cent, but once it exceeds 2 per cent its effect becomes distinctly noticeable. This action must also be considered as corrosion. Even in such cases, however, exceptionally rapid wear should not always be attributed to high sulphur content; the heavier fuels which have a high sulphur content also have high viscosity, high Conradson value, and measurable ash content.

In many instances it has been proved that the use of a heavy fuel, or "boiler oil," affects the rate of wear more than anything else. This reaction between fuel and engine is probably due to incomplete combustion, but its mechanism is not yet clearly understood. Attempts to correlate this phenomenon with certain analysis data of the fuel have not been completely successful, but it would seem that usually a high Conradson carbon value will result in a high rate of wear. Conradson figures of 2 to 3 per cent show a definite influence in low-speed engines. However, in several cases Conradson carbon figures between only 1 and 2 per cent have caused a noticeable increase in wear in high-speed engines of 800 rpm and more. The important conclusion to be drawn from this is that unsatisfactory combustion of a fuel containing no sulphur at all can cause more wear than effective combustion of a fuel containing more than 2 per cent sulphur.

A few years ago a test, with the most striking results, made in the Delft laboratories of the Royal Dutch Shell, showed the effects of a heavy fuel on wear on cast iron and on a chrome-hardened bore. A 200-hr run was made with an engine under very severe load conditions, that is, 120–125 psi imep, with varying cooling water temperatures, on fuels ranging from light distillate with 0.75 per cent sulphur up to boiler fuel with a viscosity of 4000 in. Redwood I at 100 F, 10–12 per cent Conradson carbon, 2.5 per cent sulphur, and 0.1 per cent ash.

Despite the heavy load, the severe conditions, and the worst fuel, the results were astonishing:

Cylinder wear on alloyed cast-iron bore.....	0.040 in.	per	1000 hr
Cylinder wear on chrome-plated bore.....	0.004 in.	per	1000 hr
Increase in ring gap on cast-iron bore.....	0.160 in.	per	200 hr
Increase in ring gap on chrome-plated bore.....	0.004 in.	per	200 hr

They parallel those obtained in certain Dutch ships equipped with two-stroke engines and using the cheapest possible fuels.

But why cannot this problem of the cause of cylinder wear be approached from an entirely different angle? For example: Create conditions under which cylinder wear is reduced to a considerable extent under all circumstances, and then find out in what way such new conditions have affected the engine. Application of chromium will do this; there is no doubt that a good sound coating of chromium reduces wear to an amazing extent. Fig. 1 shows the results obtained some six years ago in the laboratories of The Institution of Automobile Engineers in London. The wear of the chrome bore is about one seventh of the wear of the cast-iron bore. It is of particular interest to note that the wear of the top ring running in the chrome bore is about one fourth of the wear of the top ring running in the

Presented at the Fourteenth National Meeting of the Oil and Gas Power Division, Kansas City, Mo., June 11–14, 1941, of The American Society of Mechanical Engineers.

cast-iron bore. Both rings were ordinary cast-iron rings. A resistance to wear of 15 to 1 is not unusual. At the same time, ring wear is reduced to one fourth to one fortieth of the previous average and groove wear is appreciably decreased.

For many years engines with chrome-hardened cylinders and with plain cylinders, running under various conditions, have been closely watched. Some of them were experimental engines run for the sole purpose of determining wear, the factors that cause wear, and means that may lead to resistance to wear. Hundreds of engines in ships or out in the field have been inspected. After all there are now well over a hundred thousand

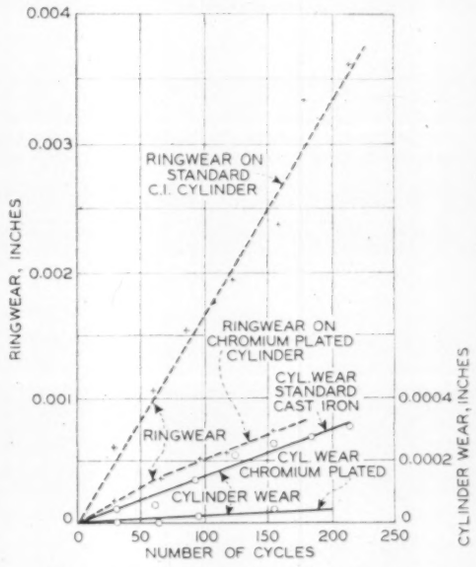


FIG. 1 CYLINDER WEAR TEST CONDUCTED BY THE INSTITUTION OF AUTOMOBILE ENGINEERS (BRITISH)

(The operating cycle involves 5 min idling, 10 min under power, followed by 15 min cooling to about 50 F.)

engines running, chiefly Diesel, with chrome-hardened bores, so there is plenty of material from which to draw conclusions.

Returning to the list of probable causes of wear, the chrome-hardened bore has the following effects on some of these factors.

CORROSION—ABRASIVE WEAR

There is hardly a better condition for corrosion—or should it be called worse?—than the two-stroke-cycle engine idling or with a little load. Add to this the use of a heavy fuel and some leaking of water into the cylinder, and the stage is set. A ship with a two-stroke double-acting engine of well-known European make was inspected by some engineers of the Delft laboratories of the Shell group. (She is at the bottom of the English Channel now.) The first thing discovered was that the dirty cylinder wall, as taken from the engine, could be washed clean with cold water. The analysis of the substance scraped off the cylinder wall showed incredible results, the largest content by far being sulphate of iron. Many more large ship Diesel engines have been inspected, and the so-called oil on the cylinder wall analyzed; 3 to 4 per cent of free sulphuric acid is nothing unusual. The application of chromium in such cases helps considerably, on the average reducing the wear to one fifth, and yet this is the least favorable result. The conclusion is that chromium corrodes too, but at a rate of only about one fourth that of alloyed cast iron.

With abrasive wear the application of chromium is far more effective, reducing it one fifteenth to one fortieth. A good example of mainly abrasive wear is found in a report on cylinder wear of 2-RBL engine No. 26060 fitted with chrome-hardened cylinders and 2-RBL engine No. 27004 fitted with nitrided liners, both at Messrs. Boams' Sand Works, King's Lynn, England. The test was made on a Dorman-Ricardo high-speed Diesel engine. The engine with chrome-hardened bores had first run for 1500 hr in the plant driving a shaft, during which time there was no cylinder wear at all. The wear after 1300 hours' run of both engines is recorded in Table 1.

TABLE 1 CYLINDER DIAMETERS OF ENGINES NOS. 26060 AND 27004

(Standard size of bore, 4.725 in. A-B is thrust and antithrust, C-D is in line with crankshaft)

Engine No. 26060 With Chrome Bores

No. 1 bore			No. 2 bore	
Diam A-B, in.	Diam C-D, in.	Distance from top of bore, in.	Diam A-B, in.	Diam C-D, in.
4.7265	4.726	5/8	4.726	4.7255
4.725	4.725	2	4.725	4.725
4.725	4.725	3 1/2	4.725	4.725
4.725	4.725	5	4.725	4.725

Both bores were in excellent condition. Slight wear had taken place at top of ring travel, but did not extend for more than 1/4 in. down the bore, otherwise the cylinder block was as good as when originally fitted.

Pistons. Both pistons were in very good condition, no excessive wear had taken place, and the diameter was standard. No. 1 groove had worn sideways approximately 0.002 in.; all other grooves were not worn.

Rings. Rings were dismantled from the pistons and tested in bores for gap. No. 1 rings had gap of 0.015 in. as compared with the original gap when fitted of 0.010 to 0.012 in. This proves that very little wear had taken place on the diameter of the ring, but 0.001 in. wear had taken place sideways. The remaining rings showed no wear in respect to either the gap or the diameter.

TABLE 2 ENGINE NO. 27004 WITH NITRIDED BORES

No. 1 bore		No. 2 bore	
Diam A-B, in.	Diam C-D, in.	Diam A-B, in.	Diam C-D, in.
4.732	4.737	4.730	4.735

It will be seen that No. 1 chrome bore is seven and a half times better for wear than No. 1 nitrided bore, and chrome bore No. 2 is ten times better than nitrided bore No. 2.

Fig. 2 refers to a series of tests with Lister Diesel engines,

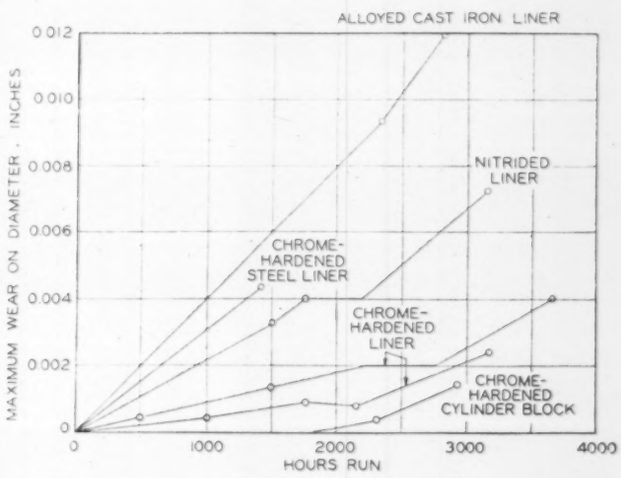


FIG. 2 COMPARISON OF WEAR OF NITRIDED CAST-IRON CYLINDER BORE WITH CHROME-PLATED BORE

1000 rpm, in which three runs of 3000 hr and over on chrome-hardened bores are compared with one engine fitted with a nitrided liner, one engine fitted with a nitrogen-hardened steel liner, and one engine fitted with an alloyed cast-iron liner. The wear as compared to the nitrided liner averages one third, as compared to the nitrogen-hardened steel liner averages one seventh, and as compared to the alloyed cast-iron liner also averages one seventh.

Fig. 3 again shows the wear in a 1000-rpm Lister Diesel engine after a 5000-hr run of a chrome-hardened linet and of a nitrided liner; this time, however, as the wear occurs as meas-

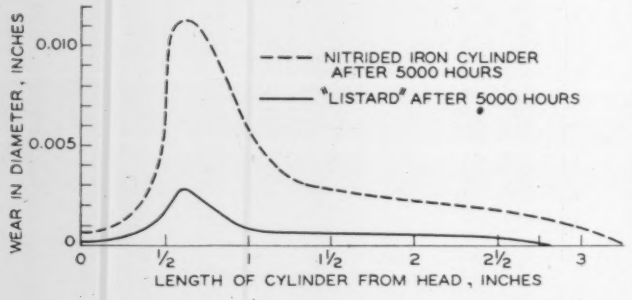


FIG. 3 COMPARISONS OF WEAR OF VARIOUS CYLINDER BORES

ured from the top of the cylinder. The two bulges show that the worst wear takes place at the top and of the top ring travel. The word "Listard" is the trade name of the manufacturers in England of Lister engines for chrome hardening.

BREAKDOWN TEST CONDUCTED AT OLEAN, N. Y.

A 14 × 14 in. chrome-hardened power cylinder was run on a single-cylinder test engine at approximately maximum load for a period of 35 hours under conditions intended to promote failure of the chrome plating. The conditions were: (1) Production of lubricating-oil supply from the usual of 3000 hp-hr per gallon to 6500 hp-hr per gallon (it has been impossible to reduce lubrication below 4000 hp-hr per gallon on plain cast-iron cylinders without scoring); (2) sudden change of cooling-water temperature from 200 F to 50 F; and (3) elimination of oil cooling to power piston which allowed the piston to seize the cylinder.

The chrome-hardened surface was not damaged by any of these conditions (except in the case of piston seizure), indicating that the chrome hardening provided a better running surface than plain cast iron. When the piston seized, metal was torn off the piston and built up on the cylinder walls at the points of greatest seizure. This did not indicate failure of the chrome-hardened surface since the chrome was not torn off the cylinder.

Rate of wear on the chrome-hardened surface was not determined since the test was carried out over a short interval of time.

SUMMARY OF TESTS

The tests were run on a two-cylinder angle engine equipped with one power cylinder. The engine was loaded by using a 29 × 14-in. type V.T.R. compressor cylinder. A 12 × 15-in. Roots blower was used to furnish scavenging air for the engine. All tests were made at 300 rpm with a load of approximately 100 imep.

After running the engine for about four hours with the lubricator adjusted to 3000 hp-hr per gal, the cylinder was examined and found to be in perfect condition. The lubricator was then adjusted to 6500 hp-hr per gal and engine ran five hours at maximum load. Inspection of the cylinder showed it to be in perfect condition. The engine was then operated for approximately three hours, during which time the water temperature was held close to 200 F, cold water of about 50 F was turned into the cylinder, and the outlet temperature was dropped to 60 F as soon as possible. Inspection of the cylinder still showed it to be in perfect condition. Following these tests the engine ran approximately 20 hours longer at maximum load while other work was being done on the engine. The cylinder had a streak in it one inch wide that extended down to the bottom of the ring travel. This mark on the cylinder looked a good deal worse than it felt and undoubtedly would never cause any trouble.

For the final test of the cylinder, the oil cooling of the piston was stopped with the intention of allowing the piston to seize. The engine ran at maximum load for approximately two hours before the piston seized and stopped the engine. The cylinder was then removed from the engine and examined. There were two places about six inches below the ports where cast iron from the piston had built up, but the rest of the cylinder looked very good, while the piston was scored nearly all the way around the circumference.

Probably one of the longest runs of an engine (which has been carefully checked) is the one in a trawler fishing from the North Sea to Iceland. By the summer of 1939 this engine fitted with chrome-hardened liners had seen over 40,000 hours of service. The liners in this four-stroke-cycle engine of 11 in. bore used to wear badly, about 0.014 in. per 1000 hours, probably due to so much idling of the engine and cooling at full capacity which reduced the cooling-water outlet temperature to no more than 40 to 50 F. It was for this reason that the engineering firm who had built the engine chose to replace the cast-iron liners with chrome-hardened liners.

The thickness of the chrome layer applied was only 0.0055 in., or 0.011 in. on the diameter. The wear figures of two of the four cylinders are as follows:

After 13,000 hr, 0.003 in. on cylinder No. 2
After 26,000 hr, 0.0052 in. on cylinder No. 2
After 15,000 hr, 0.0068 in. on cylinder No. 4
After 28,400 hr, 0.015 in. on cylinder No. 4

By this time the chrome in No. 4 cylinder was worn through on one place, but the liner was left in the engine.

APPLICATION OF CHROMIUM

The application of chromium is not an easy job. It has taken quite a few years to develop it and there have been many failures, but it is through trial and error that a process proves itself.

The process must meet certain fundamentals:

1 The electrolytic coating must adhere perfectly.

2 The thickness of the coating must, within limits, be equal all around and from top to bottom.

3 There must be no tiny ridges for the piston or the rings to run against.

4 The ordinary bright, dense coating of chromium is not suitable; it does not hold lubricating oil.

5 In order to hold oil, it is essential that the chromium be very porous.

Each of those fundamentals is very important. They are considered in detail as follows:

The necessity for perfect adherence is so obvious that it hardly needs to be emphasized. With ordinary good workmanship it is not difficult to achieve. Proper cleaning and etching of the cylinder wall together with proper tooling will always give a good adherence. Anodes are cast and machined, and fixtures made to center the anodes, as described in United States Patent No. 2,048,578.

Small cylinders or blocks are always arranged four to ten in one fixture if electroplating is done on a production basis; large cylinders of, say, 20 in. bore and over are treated one at a time.

A variation in cast iron may necessitate a variation in processing, particularly in timing, but that has to be discovered in each case. More difficult are large cylinders of 20 in. bore and over, for several reasons. The surface structure of the cast iron may vary along the cylinder from top to bottom, hence—supposing such a variation could be traced—which it cannot—the processing ought to vary on one cylinder; but this is not feasible. The machining of such cylinders is never as accurate or as good as on smaller cylinders, and this automatically varies the processing. The usual method of machining the bores of large liners is not sufficient for chrome hardening. A ground or honed finish is required. Ports in two-stroke-cycle engines are always difficult. The fact that a smooth honed surface and a rough cast surface adjoin demands a lot of the art. The edges of the ports should be rounded off so as to plate a little inside the ports.

In this connection, the following experience has been obtained: A two-stroke-cycle test engine with a chrome-hardened cylinder running at full load had been plated without rounding off the edges of the ports so that the coating of chromium ended abruptly from ribs between ports to inside ports. See Fig. 4. After a 2400-hr run, it was found that there were round bare spots where the chromium had disappeared at the corners of the ports in the direction of the air flow. What had happened? Corrosion had taken place, gradually and very slowly undereating the iron, so naturally the chromium under the full ring pressure had broken down particle by particle. The only way to prevent this is to round off the edges allowing chromium to be plated inside.

The fundamental necessity for equal thickness is also obvious. If the thickness is not equal, the bore cannot be honed clean and the rings and piston will come in contact with the rough chromium of some 1400 Brinell hardness and will abrade rapidly. Equal thickness is obtained by making suitable fixtures, centering the anodes well, and insulating those parts that should have no coating. The anode must be tapered in such a way that the lower end is slightly smaller in diameter than the upper end. This serves to counteract a tendency to deposit more chromium in the end of the bore that is down in the solution. Depositing inside a bore, there is a tendency for the chromium to taper off for the last $^3/_8$ in. at top and bottom of bore. In most engines the tapering off at the bottom does not matter, but it cannot be allowed to taper off at the top. However, an extension to the bore takes care of this. It takes practice to arrive at the proper technique of depositing just enough chromium, i.e., from 0.002 to 0.004-in. minus on the diameter measured on the rough so as to allow for honing to size.

The thickness of chromium required varies from 0.006 to 0.040 in. as measured on the diameter. In practically all the smaller engines of, say, under 6 in. bore, 0.006 to 0.008 in. is common practice, and this will last the lifetime of the engine. The proper thickness depends upon the conditions under which the engine will run and the expected lifetime of the engine. An automobile engine rarely has a longer life than 2000 running hours, but a large marine Diesel engine is still supposed to be "brand new" after 2000 hours.

The third fundamental is the necessity to avoid ridges. This has been dealt with in the explanation of the necessity for equal thickness. Such ridges may be very small and escape notice, but unfortunately the piston and rings notice them and are scratched by the 1400 Brinell chromium.

The fourth and fifth fundamentals, to the effect that bright dense chromium is not suitable and that in order to hold oil the chromium must be porous, are interesting points. When this process was first being developed some years ago and was applied to high-speed motor-car engines, it soon proved all that had been hoped for it in regard to resistance to wear. At the same time, however, the chromium and the piston skirt nearly always scored. Every precaution had been taken to make a good job of it, and in this effort the cylinders were honed to a high polish at considerable pains. Events proved that this was wrong. A superior oil was used on recommendation of experts but within a few weeks there were twenty-four engines on the test bed, and every one of them scored. At the same time other high-speed engines were performing very well

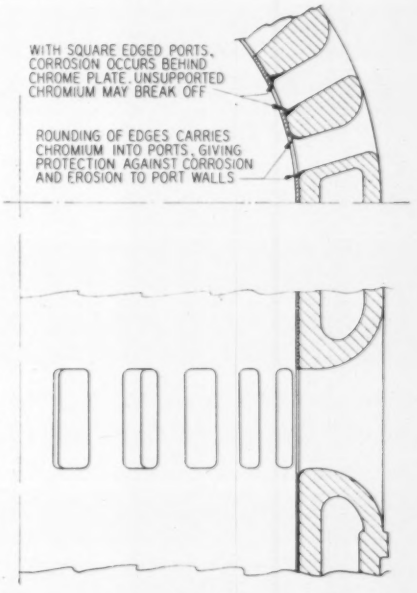

WITH SQUARE EDGED PORTS, CORROSION OCCURS BEHIND CHROME PLATE. UNSUPPORTED CHROMIUM MAY BREAK OFF
ROUNDING OF EDGES CARRIES CHROMIUM INTO PORTS, GIVING PROTECTION AGAINST CORROSION AND EROSION TO PORT WALLS

FIG. 4 TREATMENT OF PORTS OF CYLINDER LINERS FOR CHROMIUM APPLICATION

on a very ordinary mineral lubricating oil. These were inspected and it was discovered that the chromium coating on these latter engines was full of little pits. This led to experiments in an effort to produce a chromium coating that would be the reverse of a dense, highly polished finish. After a long struggle, these experiments led to success in obtaining a very porous coating of chromium, and since then cylinder scoring troubles have ceased. Contrary to a widespread trend of thought in regard to chromium coatings in cylinder bores, a dense, highly polished finish is no good.

In regard to this process it is often asked: What changes to the engine does it involve? Should there be any change in the piston clearance? What piston rings are to be used? What finish should be used on the liner or cylinder? What lubricating oils are to be used?

A short answer to these questions is: No changes at all. However, this is a bit too broad and it is worth-while to review these matters.

It has already been mentioned in this paper that the bores should be machined smooth prior to chrome-hardening by means of honing or grinding. The treatment could not be controlled closely enough if they were not. There is no change in the piston clearance and reference is made to the breakdown test at Olean, N. Y., described in this paper. There was no difference in the piston clearance, and yet the engine was not

(*Continued on page 542*)

LABOR UNDER THE DEFENSE PROGRAM[1]

By CHARLES A. MYERS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

WILL a general shortage of labor delay the defense program? What can be done to prevent shortages in certain industries? Should labor be conscripted? Are unions justified in asking for wage increases at this particular time? Should working hours per man be lengthened? What about overtime wage rates? Should labor expect to give up some of its gains of recent years? Is it not necessary to prohibit further strikes, or at least to provide compulsory arbitration of all labor disputes in defense industries?

These questions and many others like them are confronting engineers and businessmen as the tempo of the defense program continues to increase. Newspaper headlines and each person's everyday experience drive home the urgency of the problems. Emotions are strained and action is called for, often without careful consideration of the consequences. It is fortunate, therefore, that a little book[2] such as the one under review has appeared at this time. "Labor and National Defense" is a concise and cool presentation of the facts essential to an understanding of the questions just raised, and in addition, contains the recommendations of a committee of experts. It deserves a wide audience.

WILL LABOR SHORTAGES BE GENERAL?

The question of whether there will soon be general shortages of labor which might delay the defense program has, on examination, little meaning. The billions appropriated will not all be spent at once. Industries such as aircraft and machine tools are likely to reach their peak in 1942, unless all present estimates are wrong. But since it takes five years to build a battleship, employment in shipyards will continue to rise through 1943. "The fact that peak employment will be reached at different times in different industries will make possible a good deal of transference from one sort of defense work to another, thus helping to alleviate any scarcity of skilled workers." Further appropriations are not likely to require *additional* net employment so much as they are to cause a shift in labor demand from certain consumers-goods industries to armament production. The recent 20 per cent cut effected by the OPM in automobile production for the next model year is an example of what will happen. Automobile workers will be transformed into aircraft and into tank workers.

However, although the uncertainties make any estimate speculative, the increase in employment required by 1942 "will certainly exceed the number of available unemployed persons in the labor market." But even then a sudden widespread shortage need not occur. In addition to transfer from less essential occupations, other possibilities exist. New young workers will be available for jobs, hours can be lengthened further, and most important, "additional workers not normally in the labor market," such as women and farm boys, can be attracted to industry. The last, however, will aggravate the postwar problem of readjustment.

The real problem then is: How can particular shortages, already experienced in certain industries and areas, be handled? A partial answer is already found in thousands of plants, although probably not in enough. Training within industry, "on the job," is proving superior to vocational courses in schools or outside shops. "At best the type of course offered (in the latter) provides industry with a superior learner rather than with a full-equipped production worker."

Shortages of skilled workers can also be relieved through more effective use, both by workers and employers, of the office of the United States Employment Service. Or, "moving the job to the man" by subcontracting and locating new plants in areas with idle labor may develop on a larger scale. Regular apprentice training should continue in order that all-round mechanics be available in the future. Then, "if all these methods fail to relieve a shortage, it may be necessary to use the more drastic expedient of breaking down production processes into simpler elements, which can be performed by workers with only a few months' training." Many engineers and plant managers are already familiar with this "dilution" process and the accompanying progressive training known as "upgrading." Priorities and outright conscription of labor should be resorted to only when all these other methods have failed to provide sufficient workers. England has just begun to take this step.

SHOULD LABOR STANDARDS BE MAINTAINED?

Within recent years the 40-hour week has become fairly general in industry and at the same time the level of real wages has risen. Will it be possible to maintain these gains when the primary consideration is more production? The answer to the hours questions is not so simple as some persons suppose when they suggest a drastic lengthening of the work week.

Experience during the last war showed that there is a "maximum-output week," since fatigue, sickness, and absenteeism operate to reduce production at very long hours. Although the maximum will vary between industries and occupations, it is probable that the figure now lies somewhere "between 48 and 60 hours for most occupations in the United States."

Therefore, "as shortages of factory workers develop during the next two years, a general lengthening of working hours will probably be accepted without much debate. The real controversy will come over the issue of overtime payment" as required under the Fair Labor Standards Act and by numerous union agreements. The main effect of the Act is likely to be "to raise the money cost of defense production and to cause some transfer of income from taxpayers to certain groups of scarce workers." Revision of the Act would probably not reduce defense costs much, however, for unions would still insist on overtime rates and many employers would continue paying these rates voluntarily in order to attract labor from other industries. Furthermore, since increases in money wages are likely to be demanded, "there is something to be said for an increase in the form of overtime payment rather than a raising of basic rates. After the emergency has passed, reduction

[1] One of a series of reviews of current economic literature affecting engineering, prepared by members of the department of economics and social science, Massachusetts Institute of Technology, at the request of the Management Division of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Opinions expressed are those of the reviewer.

[2] "Labor and National Defense: A Survey of the Special Labor Problems Arising From America's Defense Activities and a Program for Action." The Factual Findings by Lloyd G. Reynolds (of The Johns Hopkins University). The Program, by the Labor Committee. The Twentieth Century Fund, New York, N. Y., 1941, 143 pp., paper, $1.

of hours and overtime pay would produce an automatic deflation of wages, while a reduction in basic rates might be very difficult to obtain."

The fall of France and the French 40-hour-week law are sometimes said to demonstrate the necessity for abandoning the Fair Labor Standards Act "for the duration." This is a misconception of the facts, however, for the Act does not prohibit a work week longer than 40 hours as did the French law. It merely requires the payment of time and a half for all hours over 40.

During the world war real wage rates fell because existing near-capacity production made it necessary to divert productive power from consumers goods to armaments, with the eventual result that the cost of living rose. Increases in money wage rates lagged behind living costs. Within recent months there has been a noticeable increase in retail prices, so that the earlier experience may be repeated. But some consumers goods are not competitive with armaments or defense materials and, barring an acute shortage of factory labor, enough idle capacity exists to permit expansion of output. If the volume of textiles, foodstuffs, and housing can be increased, even though new automobiles, refrigerators, and aluminum pans are fewer, the standard of living of urban wage earners (who customarily spend most of their incomes on necessities) need not be reduced.

Money wage increases in defense industries serve a useful economic function in attracting labor from less essential industries. Less justified, however, is the present tendency of employers to bid against each other competitively for skilled workers, and to recruit them from other equally essential defense areas. "Higher wages will not turn out mechanics any faster. The main effect will be simply increased turnover, which is bound to have a disorganizing effect on production." Short of outright prohibitions, the best method of handling this problem is to secure industry-wide agreements standardizing wages, thus reducing the incentive to mobility and competitive bidding. This has already been done in the shipbuilding industry on the Pacific Coast and indications are that it will be extended to other industries.

SHOULD STRIKES BE PROHIBITED?

Labor disputes are usually more frequent during a period of rising industrial activity, and the defense boom is no exception. Demands for wage increases based upon a rise in the cost of living or an increase in profits are frequently resisted by employers. Grievances multiply under the pressure for greater production, and unions find it opportune to attempt organizing drives in nonunion or partially unionized industries. Strikes are often the result, and the public, which cannot see why such things should be permitted when young men are drafted for the army, clamors for action against the strikers. The wave of bills in Congress within the last few months seeking to outlaw strikes in defense industries is a reflection of this sentiment. Yet, from organized labor's point of view, "the right to strike has been synonymous with free trade unionism, and labor regards any infringement of this right as an attack on the principle of unionism itself."

Prohibition of strikes and compulsory arbitration have been tried, and that experience is a guide in the present situation. "In no democratic country has it proven possible to prevent strikes simply by legislation." Australia has had compulsory arbitration since 1904 and Britain introduced it during the last war, yet there were a considerable number of "illegal" strikes in both countries. Both governments, furthermore, were reluctant to enforce the drastic penalties provided for violations. There are further considerations which suggest that compulsion is unwise here. During the last war, America did not find it necessary to resort to such drastic methods. And compulsory arbitration involves far more than the mere settlement of a specific dispute; in Australia wages, hours, and working conditions have been regulated on an industry-wide basis by the Court of Arbitration.

What, then, should be done that is consistent with the democratic principles we are preparing to defend? There are two possibilities. First, adjustments should be attempted through existing collective-bargaining machinery, and this union-management type of dealing should be extended to other industries as rapidly as possible. But stable relationships and the settlement of differences without strikes develop only over a period of time. So a second, supplementary procedure is necessary, especially in the defense industries, which are only partly unionized. Governmental agencies must step in.

The United States Conciliation Service has already distinguished itself in settling a number of disputes. The N.L.R.B., although essentially an agency administering the Wagner Act, has prevented a number of strikes through informal mediation efforts, and stoppages are further reduced to the extent that unions carry complaints and representation cases to the Board rather than strike. In addition to several state agencies, there is the Defense Commission, which has used its own staff to settle particular disputes.

THE COMMITTEE'S RECOMMENDATIONS

Something further has been necessary, however, and this was recognized in the research report and by the Labor Committee which made recommendations based upon the findings. This committee, composed of seven well-known authorities in labor relations,[3] suggested as one of its most important recommendations that "the present conciliation services of the government be supplemented by a Federal Emergency Mediation Board of three members appointed by the President." This recommendation was made public on March 23, 1941, four days after the President had announced the appointment of a National Defense Mediation Board of eleven members.[4] By that time it had become evident that existing agencies were inadequate to cope with growing strikes in defense industries, such as the one at Allis-Chalmers. The new Board, whose vice-chairman was chairman of the Labor Committee making the report under review, has had signal success in settling disputes after the Conciliation Service had failed to secure an agreement.

Other recommendations of the Labor Committee follow rather closely the findings of the research staff, as summarized in the foregoing. However, a few statements are worth quoting for their current interest. "Governmental standards established by law for the protection of labor should not be weakened, even temporarily, unless clear necessity therefor exists." "Every aspect of the problem of releasing and applying available energies for the defense program calls for agreement between employers and workers. Without their wholehearted cooperation, many snags will develop which will prevent management and workers from putting forth their maximum efforts." "On the part of employers, there should be not only full compliance with the laws protecting labor in its right of self-organization, but open-minded acceptance of the processes of collective bargaining. On the part of workers,

[3] William H. Davis, patent lawyer and former chairman of the New York State Mediation Board, acted as chairman; other members were: William L. Chenery, editor of *Collier's;* William M. Leiserson, of the N.L.R.B.; Frazier MacIver, vice-president of Phoenix Hosiery Company; Prof. Sumner H. Slichter, of Harvard University; Robert J. Watt, of the American Federation of Labor; and Prof. Edwin E. Witte, of the University of Wisconsin.

[4] In practice, panels of three members have been used in specific disputes.

there should be a determination to settle all controversies in defense industries without strikes." "World experience has demonstrated that the cooperation of labor cannot be gained by compulsion. Strikes in democratic countries can be prevented only by agreement between employers and workers—not by law."

"Besides encouraging the solution of labor problems by joint action of management and labor, and assisting the adjustment of labor disputes by efficient governmental conciliation service, the government can best release the energies available for production by maintaining established labor standards and good working conditions and, above all, by combating increases in the costs of living. Sharp increases in the costs of living are more likely than any other cause to produce strife which dissipates these energies and controversies which lead to strikes."

"The need to plan for the production of consumer goods along with the defense production program is directly related to the problem of how we shall meet the unemployment which will occur after the peak of the defense program is passed. Unless careful plans are made during the defense production period to meet this crisis when it comes, a disastrous collapse of employment is certain to occur. In this matter the appropriate admonition is 'in time of war prepare for peace.'"

The Chrome-Hardening of Cylinder Bores

(*Continued from page 539*)

sensitive to reducing the lubrication to half the normal and to very abnormal cooling.

Regarding piston rings, all makes of rings may be used with one definite exception. Chrome-hardened rings should not be run on chrome bores; nor should nitrided rings or other very hard rings be used. Experience shows that chrome-hardened and nitrided rings cause scoring of the bore, the piston, and the rings in a very short time.

Which lubricating oils are to be used may be answered as previously, "Make no change." Superintendent engineers who have had some years' experience with engines fitted with chrome bores have come to the conclusion that the lowest-priced oils suited them equally as well as the higher-priced. Experience has shown that any lubricating oil that promotes the varnishing of the bores, the piston, and the rings is definitely bad. It robs the process of one of its main advantages, the huge reduction in ring wear.

Some changes both in design and materials have been made by engine manufacturers applying this process. However, such changes are not a necessity. What happened is that after a year or so of experience, those items in engine design that primarily were intended for wear reduction are discarded. First to be abandoned is the dry sleeve, which is entirely unnecessary and is a nuisance. Next is the use of a plain cast iron instead of alloyed irons, resulting in less cost and often in less risk of cracking. The use of nonferrous material of a high thermal conductivity is being considered.

All in all it comes to this, that the process is much more an engineering than a purely electrochemical problem. To conduct its technique, an experienced motor engineer, who would have to learn the electrochemical side of it would be as valuable as an electrochemist who must learn the motor-engineering side of it. There are many difficulties to overcome, but the industry is used to that.

The Engineer's Responsibility in Management

(*Continued from page 526*)

these plants did I find professional engineers in control. Almost one third of them were being operated by lawyers or men who had had law training, most of whom, however, had had formal business training, too. Many of them were operated by men who had been salesmen. It seems to me that these executive and administrative jobs should be done by engineers.

A half dozen or so of the plants had just changed management. I wrote to influential directors and asked why they did not choose engineers. One interesting reply was, "Engineers know too much about too few things." To be a good manager, a man cannot afford to know about too few things. Industry is increasingly complex as the years go by, and breadth of knowledge is essential for the manager. It is eminently desirable to have a man who knows a great deal about a very few things, and at the same time knows a little about a great many things.

It is this knowing a little about a great many things that many engineers have considered unnecessary or perhaps beneath their station in life. It is the bar that stands between them and responsible positions in management.

The pressure of industrial demands today offers the engineer his greatest opportunity, through specialized formal training, permanently to break down this bar—but the motivation to do so must come from within him. It cannot be supplied from without.

DOUBLE-ENDED EYEBAR IN TENSION

(Photograph taken by W. M. Murray and shown at the Fifth Annual Photographic Exhibit held during the A.S.M.E. Annual Meeting, Dec. 2–6, 1940, New York, N. Y.)

BRIEFING THE RECORD

Abstracts and Comments Based on Current Periodicals and Events

MATERIAL for these pages is assembled from numerous sources and aims to cover a broad range of subject matter. While few quotation marks are used, passages that are directly quoted are obvious from the context and credit to original sources is given.

Continuous Growth Needed

A.S.M.E. ANTHRACITE-LEHIGH VALLEY SECTION

THE need for continuous growth in industrial enterprises was emphasized in a paper by R. DeVere Hope, consulting engineer, Newark, N. J., in an address on April 25, 1941, to the Anthracite-Lehigh Valley Section of The American Society of Mechanical Engineers.

A corporation, Mr. Hope said, can go forward in two ways: (1) The existing lines of business can be enlarged by improving the quality, reducing the cost, selling a larger percentage of the market, and in some cases increasing the breadth of the market; (2) new markets can be entered by the development of new products and new departments to handle them.

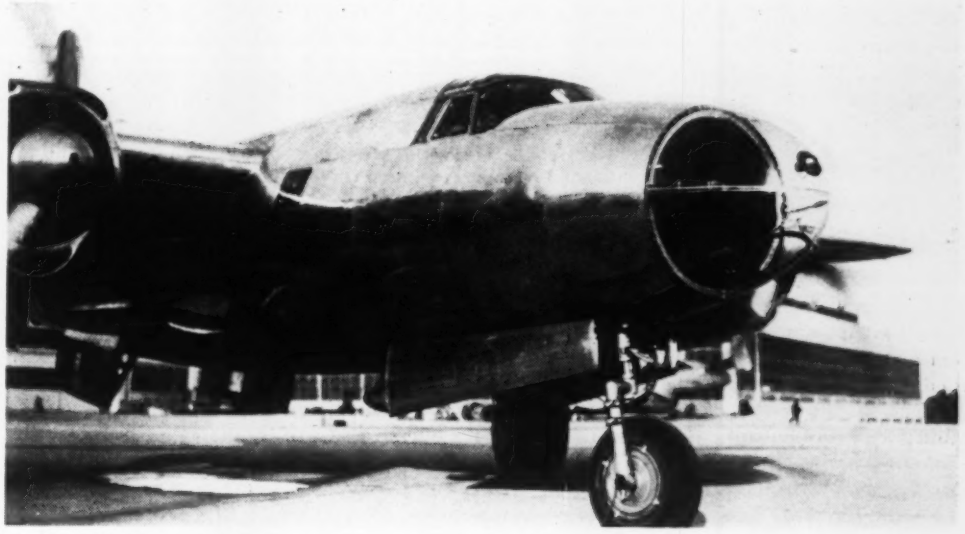
The first principle in any campaign to develop fundamental improvements in textile machinery or processes is to commence with a full analysis of the characteristics of existing machines or processes. The proper application of analytical mechanics can provide information at much lower cost than can a direct experimental attack upon the problem, and frequently the information obtained is more complete and more broadly applicable than are experimental data alone. Considerable money can be saved in the basic development by proceeding in a cautious, orderly manner. Many difficulties can be overcome on paper.

It is not sufficient to make a successful introduction of new processes, however. Continual improvement is necessary to hold a leading position in any line of endeavor.

In retrospect it appears easier to break into a new business than to maintain one's position in an established enterprise. To maintain one's position in industry, design and manufacturing must be such that costs can be obtained that will justify prices which are not so high as to tempt others to cut under them. The product should have outstanding features which make it possible to sell against competition. It is always necessary to be preparing new designs and processes against the day when another step forward is required. In styling and design a policy should be established in regard to the frequency of change, probably about every five years. Very few manufacturers of textile machinery are ready for fundamental redesign once every 25 years, let alone once every five years as in the electrical-machinery business, and approximately every two years in the aircraft industry.

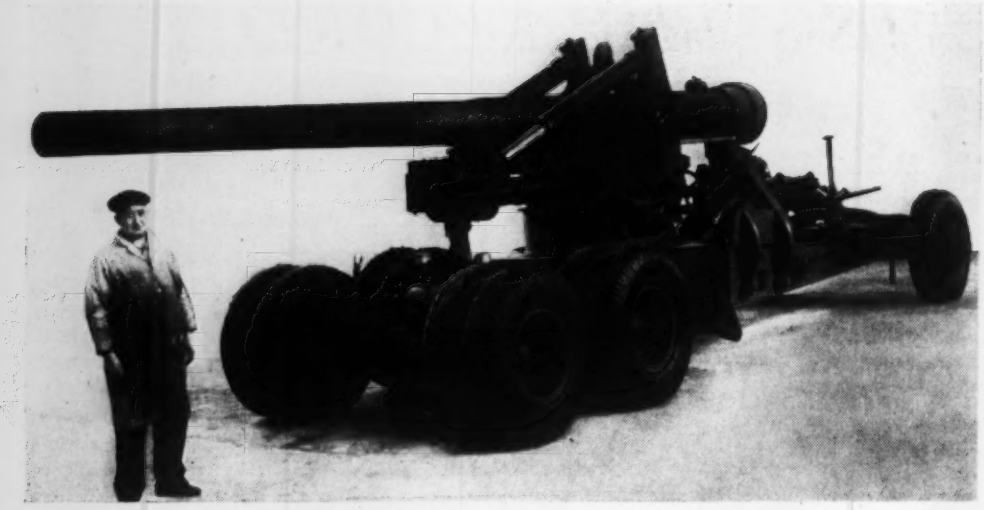
In the automotive industry, success has surely been due largely to engineering development and rapid change of design as well as manufacturing processes. The industry has always been willing to submit to severe competition and in consequence it has, year by year, built more and better cars and sold them for lower prices. In further consequence, it has made the greatest increase in employment and pay rolls, and is the most prosperous, of any of the great industries. Other industries are taking notice and considering its ways. About ten years ago Dr. Kettering of General Motors said that as soon as engineering improvement stopped, there would be no money in the automobile business for anyone. He said it was only the continous improvement which made it possible for companies to get profitable prices for their cars, and as soon as all cars were exactly alike they would stop making money. They all have learned and demonstrated that continuous progress is essential to existence, and that the more rapid the progress when well directed, the greater the profits.

Compared with the automobile industry, where does the textile industry stand? A survey made by *Fortune* in the autumn of 1940 in connection with industrial progress showed that the textile business received the greatest number of votes for having made the least technological progress; railroads and building closely followed. The textile field has been wait-



MARTIN B-26 BOMBER USES TRANSPARENT PLASTIC

(Plexiglass, a crystal-clear shatterproof plastic, is used for the tail gunner's enclosure, tail empennage, rear gunner's turret, navigator's hatch, and four side windows, as well as the nose section. The plastic can be formed on a mass-production scale into perfectly streamlined parts, strong enough to support machine-gun mounts and air pressure of dives at 400 mph. In fabrication the sheets are heated until soft and pliable, drawn over cloth-covered molds, clamped in position, and, when cool, trimmed with saws, polished, and mounted in the plane.)



MEN AND MACHINES AGAINST TIME

(First 155-mm gun carriage completed by private industry, at Dunkirk, N. Y., plant of American Locomotive Company, turned over to government officials on May 15, 1941.)

ing a long time for technical improvement in both machines and processes.

With much to be done in the textile industry and in other fields, especially now with a very hazy future ahead, engineers, inventors, and executives of skilled training, with culture and broad vision, are surely needed more than ever before. With so much energy going for defense, what of the future? If the same energy, engineering skill, and thought could be put in demobilizing industry that is now being expended in defense effort, going back to a peacetime economy might involve the discovery and development of new processes and new products for civilian consumption that could be manufactured on the same machines that now are turning out products that are useless in times of peace . . . . . Plans should be studied for the absorption of our newly trained labor in peacetime pursuits. If these things can be brought about, we shall see a world vastly different from what we have ever seen before. In the past, engineers have been highly skilled in the mechanical arts but lacking in broad scope. There are problems in the world today which cannot be tackled by precise calculations such as engineers and physical scientists have been accustomed to work with. We have narrowed training by too elaborate preparation for the first job. Interest must be aroused which will impel young engineers to study society as well as science, men as well as machines. The real efficiency will be the combined results of the machines and the human factor.

Take the fountain pen as an example. It must be combined with a human operator to produce results. If the operator is ill or is not happy, he may be regarded as having, say, a 30 per cent human factor. The 100 per cent machine in his hand gives then a net result of machine and man of 100 times 30, or 30 per cent. If the pen has no ink the efficiency is zero even when multiplied by an Edison. If, on the other hand, the operator is without a brain, the product will again be zero, although the machine may be in 100 per cent condition.

A study of these facts involving fountain pens and men develops a fundamental formula of great value. It applies to all processes involving men and machines. The efficiency of any such combination is equal to the efficiency of the man times the efficiency of the machine.

In many plants the equipment may remain unchanged but the human value can be improved by instruction and incentive, and the best incentive should come through the pay envelope. This result is in agreement with the formula and will be improved in exact ratio to the human factor. Therefore, in many cases, without spending money for new machinery in existing plants, economies can be brought about by conscientious effort upon the improvement of the human factor.

Most textile firms in existence today were the pioneers who reached out years ago for frontiers. They started with the old historical Slater textile mill in New England, and moved to Pennsylvania, Virginia, Georgia, and other points, always seeking some advantage—usually lower labor costs, fewer taxes, free water supply, and the right of stream pollution—but seldom did they apply to their progress the kind of engineering precepts that I am referring to. The physical geographical frontier which served our nation in so many important ways is gone, and gone forever. No doubt we shall continue to find new locations for profitable textile mills. A few new oil fields will be developed, and additional mineral deposits will be exploited. All of this will go on continually for many years, yet the total effect will be small.

The chief cry of the textile business, as of several other industries, has been overproduction, although we have never had an adequate general standard of living. Labor has sometimes blamed technological improvement, when it is on technology alone that we can hope for higher standards for the future.

What shall we do in the face of an industrial emergency so fundamental? Two courses are open. We can readjust our industrial institutions to a future of limited opportunity for men and for money, with an outlook keyed down to safety as our objective instead of the old purposeful advance toward a better future. The alternative is that we find an equivalent of the lost frontier—an equivalent which will as effectively open new opportunities for men and for capital.

There surely can be no question as to the physical possibilities of raising the standard of living. We have most of the materials required (at least we did have until the recent defense program). The very abundance of our national resources, fertile soil, and manufacturing facilities have embarrassed some of our governmental institutions, until we have imagined abundance to be a curse instead of a blessing.

We are favored as well in the character of our population. We have practically every skill and native ability that could be asked for. Finally, years of experience have produced a body of business and technical experts directly adapted to the production and distribution on a large scale, and on a still much larger scale after the war, at low cost and with minimum human effort, of a rich variety of desirable goods and services.

Quite obviously this new frontier of the higher standard of living offers the same advantages as did the old physical frontier now gone. We seek more and better goods and services at less relative cost. This can be attained to a desired degree only by expansion and refinement of our productive machinery and processes, only by applying the proper kind of engineering and technological principles.

Our progress toward a higher standard will thus definitely provide the opportunities for men and for money that were formerly furnished by a physical frontier. It must be clear that each of us has his own particular interest and responsibility in these matters. We cannot sit idly by and see the choice made for us. If faced with the disappearance of the physical frontier, we resign ourselves to accepting that fact as final and key our hopes down to that dismal decision—there will be little future for us or for our children. If, on the contrary, we make the more courageous decision to replace this lost physical frontier with the new social frontier of a raised standard of living, then the next generation will come into its own.

The raised standard of living demands more goods and services of better quality and at lower cost. This is a service that technology and industry is qualified to render. We are faced with these alternatives—to retreat or to advance. Is there any doubt as to which the American people should choose? Nay, rather, is there any doubt as to which they will choose?

Tacoma Narrows Bridge

FEDERAL WORKS AGENCY

FAILURE of the Tacoma Narrows Bridge, on Nov. 7, 1940, aroused the interest of the entire world. Seldom has a great engineering structure failed under circumstances that permitted a motion-picture record of its most interesting stages and seldom have such pictures brought to the public and to engineers such a convincing demonstration of the effect of oscillations caused by wind. Ever since the failure the engineering press has been flooded with descriptions of the bridge and its spectacular collapse, and comments by engineers on causes and cures. On March 28, the board of engineers, consisting of Othmar A. Ammann, Theodor von Kármán, member A.S.M.E., and Glenn B. Woodruff, appointed by John M. Carmody, administrator, Federal Works Agency, rendered its report, which has been made public.

The report is a well-illustrated document of 139 pages supplemented with appendixes covering special features of the board's studies from which the following "Summary of Conclusions" is quoted:

As a result of the investigations which are described in detail in this report, we have reached the following conclusions:

1 The Tacoma Narrows Bridge was well designed and built to resist safely all static forces, including wind, usually considered in the design of similar structures. Its failure resulted from excessive oscillations caused by wind action.

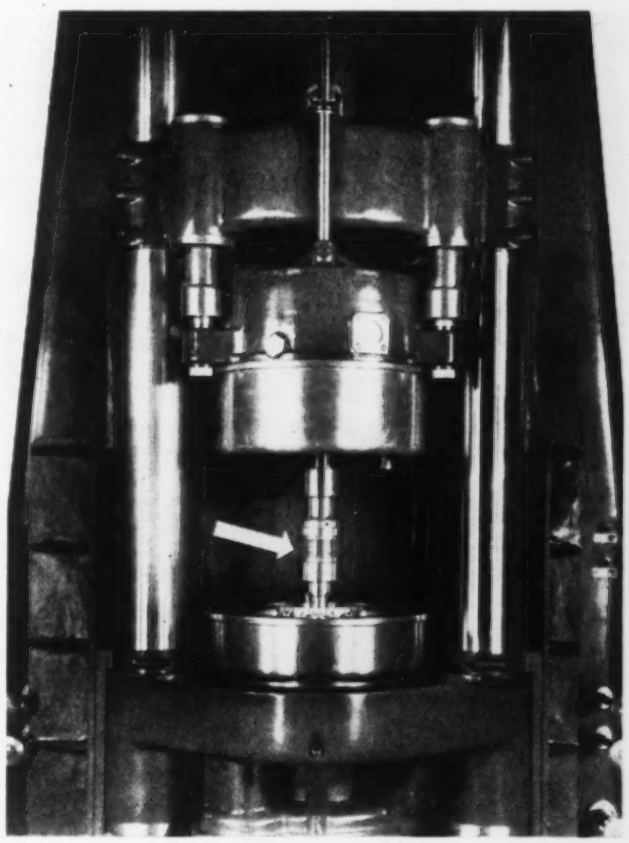
2 The excessive vertical and torsional oscillations were made possible by the extraordinary degree of flexibility of the structure and of its relatively small capacity to absorb dynamic forces. It was not realized that the aerodynamic forces which had proved disastrous in the past to much lighter and shorter flexible suspension bridges would affect a structure of such magnitude as the Tacoma Narrows Bridge, although its flexibility was greatly in excess of that of any other long-span suspension bridge.

3 The vertical oscillations of the Tacoma Narrows Bridge were probably induced by the turbulent character of wind action. Their amplitudes may have been influenced by the aerodynamic characteristics of the suspended structure. There is, however, no convincing evidence that the vertical oscillations were caused by so-called aerodynamic instability. At the higher wind velocities torsional oscillations, when once induced, had the tendency to increase their amplitudes.

4 Vertical oscillations of considerable amplitude were first observed during the erection of the suspended floor and continued, at intervals, until the day of failure. While, at times, the resulting stresses in the stiffening girders were high, there is no evidence that any structural damage resulted. Under certain observed conditions very high stresses were caused in the ties which connected the suspended floor structure to the cables at mid-span.

5 It appears reasonably certain that the first failure was the slipping of the cable band on the north side of the bridge to which the center ties were connected. This slipping probably initiated the torsional oscillations. These torsional movements caused breaking stresses at various points of the suspended structure and further structural damage followed almost immediately. The dropping of the greater part of the suspended structure of the center span was made possible by the failure of the suspenders. This was followed by the sudden sagging of the side spans with resulting bending and overstressing of the towers and of the side spans.

6 The suspension type is the most suitable and the most economical that could have been selected for the Tacoma Nar-



APPLICATION OF INDUCTION HEAT-TREATMENT

(Application of induction heat-treatment to the bores of cast-iron cylinder liners used in its entire line of Diesel tractors has been announced by the Caterpillar Tractor Company. The photograph shows the heat head and quenching device of the Budd induction heat-treating machine used in the process. The cylinder liner (not shown) is held in place by chucks while the head (indicated by the arrow) travels along the axis of the bore. The installation makes it possible to control the hardness, depth of penetration, and the area of the bore treated, and produces a longer wearing sleeve with markedly improved physical properties, it is claimed. The movement of the head, application of the current, and operation of the quench are all entirely automatic, thus removing any possibility of error in the process. The machine is placed directly in the production line and thus trucking or handling of parts between the line and heating ovens is eliminated. One operator is required and the whole cycle of treatment takes but a few seconds. The machine is a development of Budd Induction Heating, Inc., a subsidiary of the Budd Wheel Company of Detroit.)

rows Bridge. No more satisfactory location would have been chosen.

7 Both the Public Works Administration and the Reconstruction Finance Corporation were entirely justified in assuming that, because of the experience and reputation of the consultants employed by the Washington Toll Bridge Authority, there could be no possible question as to the adequacy of the design. Both agencies exercised thorough and competent supervision during the construction of the bridge.

8 There can be no question that the quality of the materials in the structure, and the workmanship, were of a high order.

9 Certain parts of the towers were severely overstressed and permanently deformed during the failure. While there is no visual evidence of damage to the cables, except at the center of the north cable, it is probable that they were overstressed during the torsional oscillations and as a result of the sagging of the side spans. The main piers were not damaged, except locally, during the failure and can withstand considerably heavier tower reactions than they received from the bridge as it existed. The anchorages were not damaged and are safe for forces not greater than those imposed by the original construction.

10 The criteria usually considered for rigidity against static forces do not necessarily apply to dynamic forces.

11 The remedial installations in the bridge represented a rational effort to control the amplitudes of the oscillations. Further installations, including diagonal stay ropes from the top of the towers to the floor were being investigated when the failure occurred, and these would have increased the rigidity. It is doubtful that any measures of this nature would have been sufficient to compensate for the extreme flexibility of the structure.

12 The evidence as to whether the vertical oscillations of the bridge would have been affected by fairing (streamlining) is inconclusive. There is certain evidence that fairing would have had an unfavorable influence on the torsional stability.

13 Further experiments and analytical studies are desirable to investigate the action of aerodynamic forces on suspension bridges.

14 Pending the results of further investigations, there is no doubt that sufficient knowledge and experience exist to permit the safe design of a suspension bridge of any practicable span. The results of further research should furnish knowledge that will permit of more economical design.

15 This report has been restricted to the Tacoma Narrows Bridge, except that available information from other bridges has been considered.

"Hipersil"

WESTINGHOUSE EDITORIAL SERVICE

ANNOUNCEMENT has recently been made of a joint research development of Westinghouse Electric & Manufacturing Company and American Rolling Mill Company of an improved magnetic material called "Hipersil" which, as the name indicates, is a high-permeability silicon steel. It is claimed that Hipersil as used in transformer cores has one third greater flux-carrying capacity for the same magnetizing force than that of the best conventional silicon steel, and that its losses are no greater. Furthermore, its magnetostriction, or change of dimensions with magnetization, is lower so that the increased flux density at which it operates causes no increase in transformer hum. In its first application it has reduced the size and weight of distribution transformers as much as 25 per cent, has facilitated reduction of copper losses some 10 per cent, and thereby increased short-time overload capacity.

A crystal of any magnetic steel is cubical in form; it is easily magnetized along its edges, less easily along its diagonal. If these molecules could be packed face to face like toy building blocks in a tray, the material would be easily magnetized in any one of six directions. Such a steel would be perfectly "grain-orientated." Ordinary silicon steel has little or no grain orientation, but the special process of producing Hipersil results in orientation in one direction (that of rolling); hence the material is easily magnetized in this direction.

FIG. 1 TRANSFORMER CORES OF HIPERSIL STRAPPED TOGETHER WITH STEEL BAND

Its flux-carrying capacity in this direction is almost one third greater than that of conventional hot-rolled silicon steel, but used at right angles to the grain it would be much less effective than the older material.

It will be realized that in order to take advantage of the higher directional permeability of Hipersil in a transformer core, the path of the flux must be in the direction of rolling of the steel. This is accomplished by winding a strip of the steel like a roll of ribbon about a rectangular block to form a core resembling an elongated doughnut of rectangular cross section and center opening. The formed core is then plastic-bonded and sawed in two at

right angles to the direction of winding. Coils are slipped over the legs, and the two parts of the core are strapped together with a steel strip.

This type of construction makes it simple to repair a transformer by separating the two halves of the core and replacing the coil with a new one.

Although the methods of manufacture of Hipersil have not been divulged, it is stated that the partial crystal orientation is obtained by a combination of rolling and heat-treating processes.

A Micro Hardness Tester

ZEITSCHRIFT FUR METALLKUNDE

THE *Engineers' Digest* for February, 1941, abstracts a paper by Heinrich Hanemann and Oskar Bernhardt entitled "Ein Mikrohärteprüfer" which appeared in *Zeitschrift für Metallkunde* for February, 1940.

Hardness testing by Brinell, Rockwell, and Vickers methods affects a large number of crystals. This means that not only the crystalline plastic deformation, but also distribution, magnitude, and number of the crystals influence the result.

Until now, microscopic hardness-measuring methods have not been adopted, apart from the examination of scratch hardness and abrasive hardness. The last two methods, however, measure rather the resistance to wear than the plastic deformation. A new method developed by E. M. Lips is based on microscopic measurement of plastic deformation. The results are expressed in the same units as the standard hardness numbers, and hence are comparable within certain limitations.

Micro hardness testing can be split up into several stages: (*a*) Location of the exact point where examination is to take place; (*b*) impression; and finally (*c*) measurement of impression. Stages (*a*) and (*c*) require an optical instrument, while (*b*) necessitates a mechanical arrangement. Both can be designed with an interchanging device to bring the optical axis of the instruments into the same line in turn. But when it comes to hardness testing of individual crystals with dimensions of only a few microns, the accuracy of the mechanical device is insufficient.

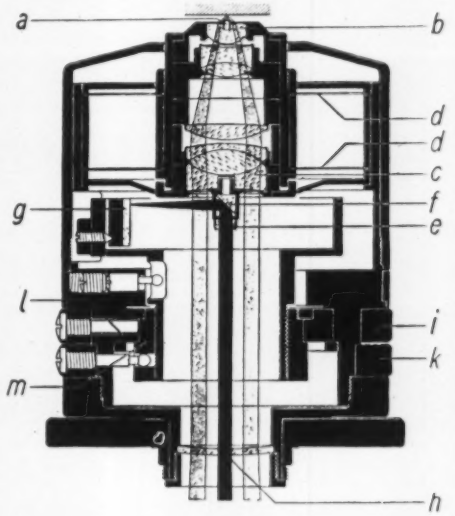


FIG. 2 SCHEMATIC CROSS SECTION OF THE MICRO HARDNESS TESTING MACHINE, TYPE ZEISS D.30

[(*a*) Diamond pyramid; (*b*) front lens; (*c*) eyepiece; (*d*) ring-shaped springs; (*e*) auxiliary objective; (*f*) mirror; (*g*) scale for test load; (*h*) correcting lens; (*i, k*) graticule disks; (*l*) eccentric for fine adjustment; (*m*) spindle for zero adjustment.]

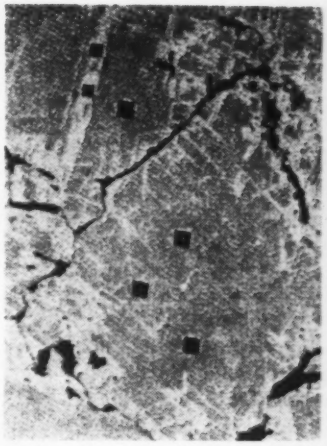


Fig. 3

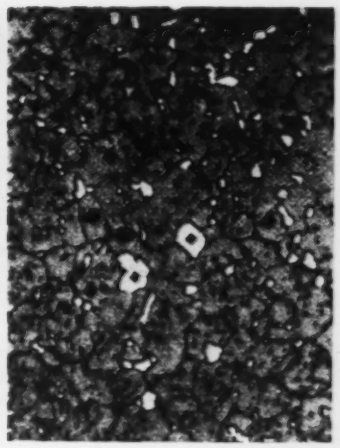


Fig. 4

FIG. 3 MAGNETITE WITH HEMATITE PRECIPITATION ×400

Hardness { Magnetite 690 kg per sq mm / Hematite 1100 kg per sq mm } Test load 50 g

FIG. 4 HIGH-SPEED TOOL STEEL ×850

Hardness { Carbide 3300 kg per sq mm / Martensitic matrix 1500 kg per sq mm } Test load 5 g

The new micro hardness-testing device eliminates the interchanging mechanism by unifying the indentor with the lens. A diamond pyramid is fixed to the center of a lens, leaving a ring-shaped part of the lens free for illumination and inspection of the test sample. Part of the light beam, entering the lens through a small angle of aperture, is cut out. An 8-mm apochromatic objective of 0.65 numerical aperture is used, of which the front lens has a diameter of 2.3 mm. The diamond is 0.8 mm diam.

This optical arrangement is fixed to a mechanical device for measuring the loading (Fig. 2). Ring-shaped springs are used to take up the lens, since the loads transmitted are very small (0.2 to 100 g), and the friction of the load-transmitting mechanism should be as small as possible. The magnitude of the deflection of these springs is a measure of the test load. An auxiliary objective is introduced (*e* in Fig. 2) between the objective and the vertical illuminator. This auxiliary objective occupies that part of the beam which is useless for examination owing to the presence of the diamond pyramid. The auxiliary lens, together with a mirror (*f*) at 45 deg serves to illuminate a scale (*g*) fixed to the casing of the instrument. The test load on the objective causes bending of the disk springs and shifts the auxiliary lens by the same amount along the line of light beam. The scale is adjustable in every direction, hence, the possibility of a zero adjustment.

A special eyepiece, used for measuring the impression, is fitted with a micrometer spindle and two graticule disks rotating in opposition to each other. Two angular locating marks are arranged so that in the zero position of the microscope they form a cross, and in any other position they form a square of measurable dimensions. Since the eyepiece is laterally adjustable in the tube, the cross position of the mark is used to mark the position of the impression. The mark is also used to take readings of the loading. The area of the impression can be determined if the angular marks are shifted by an amount equal to the side of the impression. If the impression is not square, it can be easily converted to a square of the same area.

The instrument is simple to handle. The surface of the sample is brought into focus and the sample so arranged that the crystal to be tested comes in the correct position. The objective is then

lowered onto the specimen until the test load is reached. Measurement of the impression follows.

The hardness of solid solutions in which precipitation of a second phase has occurred can be measured, since it is almost always possible to find places free from the precipitate (Fig. 3). The variation of hardness in thin layers such as in electroplating and nitride hardening can be determined.

The hardness of high-speed tool steel is determined by measuring the hardness of the carbide and the martensitic matrix independently. Substances which were regarded as brittle can be examined for hardness if small test loads are used. Under such conditions plastic deformation of the substance results.

This method could be adopted to determine the hardness of minerals too. Even minerals like corundum and spinel show plastic deformation. The method has been used with silica and kindred substances with good results. [See page 566 of this issue, Bibliography on Induction Heat-Treatment—EDITOR.]

Air- Vs. Liquid-Cooled Aircraft

JOURNAL OF THE AERONAUTICAL SCIENCES

IN THE April, 1941, issue of the *Journal of the Aeronautical Sciences*, John G. Lee compares the performance of aircraft with air-cooled and liquid-cooled engines.

Data are presented on the drag, weight, cooling, and fuel consumption of both types of installation. Based upon these data there is postulated the design of three groups of air-cooled and liquid-cooled airplanes—pursuit planes, bombers, and commercial flying boats. The two types in each group are then compared on both a power and weight basis.

Mr. Lee concludes that on the basis of equal weight, equal cleanness, and equal maneuvering characteristics, the air-cooled installation can equal the speed of the liquid-cooled, and surpass it in take-off, climb, and ceiling. When range and weight-carrying ability are the primary considerations, the air-cooled has every advantage. In view of this situation, it is only proper to ask why are not all the engines of the warring nations of the air-cooled type? The answer is not technical; it is practical. The Germans have specialized in liquid-cooled engines ever since the last war. What few air-cooled types they have built have been of American design, built under license. Judging by the fact that the Germans continued to buy American radials for some years, it may be inferred that they never really mastered the air-cooled types. The English have built both types, as did the French. However, the application of Meredith's ducted radiators to the liquid-cooled pursuit planes in advance of the time when his principles were applied to the air-cooled pursuit, gave the liquid-cooled type a temporary speed advantage. This advantage came at the time England was going into war production, so it was natural that her pursuit planes would be built around liquid-cooled installations, while her bombers used the air-cooled.

Serviceability, vulnerability, or engine cost have not been discussed. These are difficult qualities to handle quantitatively. A very good qualitative case can be made for the superiority of the air-cooled engine in regard to serviceability and vulnerability. A bullet through the cooling fins or the baffles, for instance, will not stop an engine. There are definite records of an air-cooled engine continuing to run with a bullet hole through the cylinder and the piston. A bullet through a water jacket brings a plane down. An air-cooled cylinder can be replaced, but a liquid-cooled engine requires a whole new cylinder block. As for cost, those figures which have come to the writer's attention indicate much higher costs for the liquid-cooled engine, as well as for installing the engine, than for the corresponding air-cooled type. Higher cost is an indication of greater difficulty in production, and this is an important military as well as commercial consideration.

Because the Germans and the English use liquid-cooled pursuits is not an argument that we should. They made their decision at a time when they lacked important technical knowledge which we now have. They cannot change now. We are in an extremely fortunate position to have in production 2000-hp air-cooled engines—30 per cent more powerful than anything available abroad. The foreign nations would match them if they could, but they are learning, as some Americans have already learned, that to develop a really satisfactory 2000-hp liquid-cooled engine is truly a monumental task.

Of course, we must learn from the experience of other nations when that experience applies to us; but we must not copy the mistakes of other nations, nor must we accept their limitations, if they do not apply to us. When we are possessed, as we are today, of technical knowledge which was not available to them at the time when they "froze" their fighting types, we should not hesitate to differ with them. In the light of our present knowledge, comparison of air-cooled and liquid-cooled aircraft upon a basis of equal size, weight, and type, indicates that the air-cooled aircraft are superior.

ELECTRIC THICKNESS GAGE

(An instrument for measuring wall thickness of hollow aluminum airplane propellers, also applicable to thickness measurement of any nonmagnetic metal when only one side is accessible, has been built by the General Electric Company. Thicknesses from $1/4$ in. up to $1\,1/2$ in., depending on electrical resistivity of metal, can be measured within an accuracy of 5 per cent.

The gage consists essentially of a bridge circuit, voltage-amplifying equipment, and an indicating instrument. The bridge circuit comprises two inductances with U-shaped cores and a differential transformer. The inductances serve as a gage head and an adjustable balancing head.

The gage head, when placed against a nonmagnetic metal, sets up eddy currents within the metal which change the impedance of the head and affect the circuit bridge balance. The eddy currents increase with the thicknesses of the metal.

The effects of these eddy currents upon the circuit bridge, as shown by deflection of the indicating scale, are plotted upon a master curve for known thicknesses of a specific metal within the desired thickness range.

The gage head then is placed against the unknown thickness of that same metal and the scale of deflection read. This reading is compared with a similar point on the master curve to determine the thickness of the tested piece. It is essential that the contour of the test piece be the same as that of the pieces of known thicknesses from which the master curve was obtained.)

COMMENTS ON PAPERS

Including Letters From Readers on Miscellaneous Subjects

Steam-Locomotive Design

COMMENT BY F. H. CLARK[1]

The locomotive design, presented in this paper,[2] has one of the characteristics of the Garratt locomotive in that its steam-generating equipment is suspended between two units of the driving mechanism—but there the resemblance ceases. It would appear that the various elements of design were so combined as to meet the author's objectives. The paper shows careful thought in working out his plans and is very interesting.

COMMENT BY A. I. LIPETZ[3]

The author first refers to objectives to be sought in locomotive design. He enumerates seven, of which the writer will comment upon only three, 3, 5, and 7.

Objective 3, calls for a larger percentage of the total locomotive weight on driving axles so as to provide enough adhesion for the large torques required for quick starting and accelerating trains. The writer would point out that this percentage in the conventional locomotive, which has been worked out during a century of locomotive development, is not an arbitrary figure which can be changed at will in designing. It depends upon the kind of work which is required of the locomotive. In the early years of locomotive development, this percentage was 100, and later, as the speed and power of the locomotive advanced, the percentage accordingly came down from 100 to a value of 60 to 75 per cent, necessitating supporting trucks. Only when small wheels can be used for drivers, may 100 per cent of adhesion weight be specified, and then this is a restriction of weight.

As to objective 5, which calls for lowering the center of gravity of the locomotive to make it suitable for higher speeds on curves, it is questionable whether for higher speeds the low center of gravity is necessary, or desired. More than 80 years ago it was proved by locomotive builders that, for smooth running at high speeds, it is desirable to have the center of gravity higher than customary, as long as the centrifugal force of the suspended mass does not cause derailment due to dangerous tilting of the locomotive. The centers of gravity of the present-day high-boiler locomotives are as high as 78 to 80 in., located in the vertical plane of symmetry of the boiler. As long as this condition is fulfilled, there is no danger in running locomotives at 100 mph. Only lately, without proof, simply by pure reasoning, based on the theory of static stability, the low center of gravity of Diesel-electric and electric locomotives was put forward as an advantage.

As to objective 7—to obtain as many of the advantages as possible without an undue increase in weight of the locomotive per horsepower, or its length, its cost, and the maintenance expense, these are very desirable aims for a designer. But this will develop automatically as a result, if the proper design is chosen, more than as an objective.

Now, reverting to some details which evidently are considered by the author of the paper to be the desired objectives, we can state the following:

It is true that single-expansion reciprocating engines cannot compare with the steam turbine in over-all efficiency, but it is not true that the steam turbine is the only one type of steam-expansion machine which is suitable for a large adiabatic drop required for the lowest steam rates. The two-stage reciprocating engine can give very high efficiency, as proved on many French Chapelon locomotives. The Rankine cycle for two-stage expansion at atmospheric exhaust is 20.1 per cent and the practical figures, obtained from actual tests made with Chapelon locomotives, have shown a steam rate of 11 lb per ihp, corresponding to 16.6 per cent over-all efficiency. This is as good as any steam turbine can show between the same pressure limits. Only when a condenser is introduced, does the efficiency become higher. Consequently, the author's suggestion is based on the premise that a condenser, and then a steam turbine, are indispensable.

The author assumes that the only objectionable characteristic of the steam turbine is the extravagant steam consumption when the turbine is operated at speeds other than those for which it was designed. While this fact is correct, it must be said that it is impossible to operate a locomotive at the only speed for which it is designed and that every locomotive, before it reaches its optimum speed and accelerates, must go from starting through a series of different speeds. After the balance speed of a train is reached, the speed varies, depending upon the tonnage of the train and the profile of the road, and fluctuates all the time until the train is brought to a standstill. Thus, practically, never can a locomotive with direct drive run so as always to have the most convenient steam consumption. This can be attained only occasionally. The locomotive must be adapted to the most desired speed for its particular case, which, with another tonnage, may be different. In view of this, it is practically impossible to build a locomotive with mechanical transmission, on swivel trucks or otherwise, without affecting the objective of the design.

In view of the foregoing, electric transmission will probably be found indispensable in order to adjust the speed of the turbine to the most economical control of the performance, and get an economical locomotive machine. In so far as the writer is aware, this is the reason that prompted the builders of the Union Pacific locomotive to resort to electric transmission. Undesirable as electric transmission is with regard to weight and cost, it must be admitted that it is mechanically simple and well worked out in all details. The application does not involve the enormous time expenditure for research, as is called for by a mechanical direct-drive design of a turbine locomotive.

However, there is another good reason for the electric transmission, and that is reversibility. Every locomotive must be reversed, even if it is built for high-speed and one-way operation. Mechanically, it is quite complicated and possibly cannot be done simply. Much time was spent in developing a turbine locomotive before the I-1 6-4-4-6 Pennsylvania locomotive, exhibited at the New York World's Fair during its 2 years' duration, was built. Reversing of the locomotive

[1] Consulting Engineer, New York, N. Y. Mem. A.S.M.E.

[2] "Modern Objectives in Steam-Locomotive Design," by R. M. Ostermann, MECHANICAL ENGINEERING, November, 1940, pp. 801–804.

[3] Chief Consulting Engineer, in Charge of Research, American Locomotive Company, Schenectady, N. Y. Fellow A.S.M.E.

could be accomplished only by reversing the gears which connected the turbines with the driving axles, or by making a separate set of turbines for reverse. The reversibility proved to be the hardest nut to crack in the entire design of the locomotive. Unless this is simply done, or the mechanical transmission excluded by introducing the electric transmission, this problem seems to be almost unsolvable.

The author shows how gradually we come from the ultra-high-pressure and high steam-temperature requirements, which in themselves are problems awaiting a practical solution, to the idea of using pure feedwater, which demands condensation of the exhaust steam. This alone may kill the entire project. Ljungström in Sweden started this idea about 20 years ago, on the same premises as the author. After a great many years of research, on which about five million dollars were spent, he finally came to the conclusion that the noncondensing turbine must be used, if anything worthwhile is to be accomplished. Seemingly, the same conclusion was reached by the General Electric Company, as the Union Pacific turbine-electric locomotive now has an atmospheric condenser, which is being tested at the present time.

Another difficulty with the condenser is that, if this is applied, a separate drafting arrangement for the boiler must be provided. This in turn requires pumps for the water, pumps for the air and other mechanisms, which have proved to be the source of a great many mishaps and troubles. The writer does not mean to say that it would be impossible to overcome this difficulty, but it cannot be done practically without undertaking a comprehensive and expensive research.

Reverting now to Fig. 2 of the paper, in which the author gives different curves for the drawbar horsepower, curve *f* should be considered, which represents the drawbar of a 4500-hp 4-6-4 reciprocating steam locomotive. If the maximum power of this locomotive is duplicated, we must consider that at different speeds the power curve will change, and the optimum speed will be only about one half the maximum. The power will be almost nothing at zero speed and at maximum speed. It is, therefore, necessary to displace the curve in order to have the optimum at a speed sufficiently high for a high-speed locomotive. Assuming that the locomotive will have a maximum speed of 100 mph, the optimum speed should be about 80 mph. If curve *f* is so modified that the optimum should fall on the ordinate of 80 mph and the curve should follow the parabolic shape for speeds below 80 mph, it can be easily seen by drawing a new curve in Fig. 2, that the acceleration of a train figured for this new curve would be lower than that of curve *f* of the paper. It will surely not approach curve *e*, which represents the Diesel-electric locomotive, because the Diesel engine is a constant-torque machine, while the turbine is a constant-speed variable-torque machine. This is what makes the Diesel so heavy. A high-pressure, high-superheat turbine locomotive with electric transmission and condenser would be still heavier.

Then, what would we have after all the requirements were met? Evidently, the result would be a turbine locomotive with a maximum of 4500 hp, which is below the Diesel-electric locomotive shown by curve *e*, with properly misplaced transmission. With all the work of research enumerated remaining to be done, this turbine locomotive for the same power, would probably cost as much as the present-day Diesel-electric. It would be more complicated, and would have an efficiency far below that of the Diesel. Therefore, it is evident from this analysis that the attempt to develop the turbine locomotive is not worth the trouble.

The writer is sorry to be obliged to arrive at this pessimistic conclusion, but has followed the author's suggestion "to analyze the situation and to seek avenues of departure from old established locomotive-design practices." The radical propositions of the author "do not lead to the use of steam in train haulage" in a simple and cheap form. More modest requirements in the improvement of the present-day steam locomotive, without radical change in the design of the Stephenson boiler, may give us a locomotive which will be suited for high speed and modern conditions of haulage and retain the good features of the old, simple, and cheap steam locomotive.

AUTHOR'S CLOSURE

The author stated in the presentation of his paper that he feared it would prove futile for discussion in the absence of concrete proposals for the attainment of his objectives. When being confronted with the discussion of Mr. Lipetz, the author realized more fully how much his fears were justified. In fairness to Mr. Lipetz and others whose interest was aroused by the author's subject, may he be permitted to explain in this closure somewhat more fully just how he would propose to design a direct-driven condensing high-pressure steam locomotive.

Objectives 1, 2, and 4 of the paper, i.e., the desire to increase the availability of a steam locomotive, by making its maintenance less dependent upon varying water supplies, as well as the desire to improve the locomotive operation by the elimination of frequent water stops, are clearly unattainable without a successful solution of the condensing problem. Referring to Mr. Lipetz' skepticism of practical success with condensation on locomotives, the author first wishes to point out that in none of the past European attempts, including the one of Ljungström, had condensation been aimed at for the purpose recommended in the paper, i.e., for the purpose of providing pure feedwater. All of the European engineers, of whose designs and trials the author has knowledge, were tempted to condense in a vacuum in order to increase the available adiabatic heat drop in the prime mover, and to save fuel thereby. All of them encountered the physical difficulty of a low specific heat transfer between the wall of the condenser tube and the air which carried off the heat. In consequence thereof, they found that they obtained impractical weights and dimensions of condensers, as well as large power losses for driving the cooling fans. It was exactly this situation which caused Zoelly to experiment with an evaporative cooler. The latter eased the problem of heat dissipation materially but made it necessary to evaporate such a large amount of water that it detracted from the operating advantages of condensation. He and Ljungström, using stereotype boilers, limited themselves to a moderate pressure of steam generation and to a moderate adiabatic heat drop above the atmosphere, which they were only too anxious to increase by continuing the expansion of the steam within the prime mover to a pressure substantially below the atmosphere.

Zoelly makes this quite clear in a paper,[4] describing his locomotive design. He significantly stated, in that year, 1924: "It scarcely needs to be pointed out that in the case of the steam locomotive, high pressures should only be introduced after successful experience in connection with stationary power plants, ..." Zoelly then realized the thermal gain that could be derived from higher boiler pressures, but thought at the time that they were impractical on a locomotive, whereas, condensation presented the smaller practical risk in his view. Perhaps he did not clearly visualize the interconnection between boiler pressure and ease of condensation. In our modern view, condensation on a locomotive will only be considered a practical improvement if the operation of the locomotive can thereby be made entirely independent

[4] "The Zoelly Turbine-Driven Locomotive," by H. Zoelly, Trans. A.S.M.E., vol. 46, 1924, p. 1206.

of the water-supply problem, and if the heat of condensation is dissipated by air such as is available under various climatic conditions.

The greatest practical difficulty of condensation on a locomotive, i.e., the low specific heat transfer between the metal and the air, can only be lessened by designing (1) for lowest possible steam rate per effective drawbar horsepower-hour; (2) for largest possible temperature difference between the condensate and the air; and (3) for lowest possible heat contents of the steam as it enters the condenser. The first and second requirements demand a greatly increased boiler pressure and a relatively high condensing pressure. The General Electric-Union Pacific locomotive represents the first serious attempt to bring that about. Since the results of tests of this locomotive have not as yet been published, the author has not been able to determine the steam rate per drawbar horsepower-hour which was attained on that locomotive. However, there is no doubt in the author's mind that requirement (1), i.e., the lowest possible steam rate per drawbar horsepower-hour, would be best met if an efficient means for coupling a turbine mechanically to the driving axles were available, a means which would also, like a variable-speed transmission, avoid excessive steam rates in starting and accelerating a train.

In presenting his paper, the author stated, off the record, that in his view such means could be developed by compounding a variable-pressure steam turbine as a primary expansion stage, with a variable-cut-off piston-displacement engine coupled to it, preferably of a rotating uniflow type and capable of being operated without lubricating oil, as the secondary expansion stage. The author visualizes that such a compounded prime mover could be combined with a double-pressure system of steam generation and steam storage, the firing of which system would be, with either coal or oil, automatically so controlled that the maximum torque is furnished, at the moment of starting, by the engine alone; that, as the locomotive gathers speed, the engine cut off and torque would be automatically reduced, while the diminishing engine torque would be supplemented with an increasing turbine torque. This increasing turbine torque would be obtained by increasing automatically the steam-generating pressure and superheat in conformance with the rising speed of the turbine and its consequent ability to expand the offered steam to a fixed receiver pressure. In this manner, the highest heat drop is obtained when the locomotive operates with its maximum power output, and that is important for a condensing job, because the maximum weight of steam to be condensed is one of the determinants of the condenser size.

With present steam-locomotive designs, the lowest steam rates and the maximum horsepower outputs, unfortunately, do not coincide; as a matter of fact, due to inherent design limitations, the reciprocating-cylinder type of locomotive can only be forced to deliver increased power by forcing the steam generation and by utilizing the increased amounts of steam available thereby, with uneconomically long cut offs. The arrangement just outlined would, on the other hand, make it possible to obtain steam rates which continue to decrease with increasing horsepower outputs, up to the limit of the available boiler capacity. With such a fundamental design modification, the drawbar-pull and drawbar-horsepower curves, as functions of locomotive speed, would undergo significant changes.

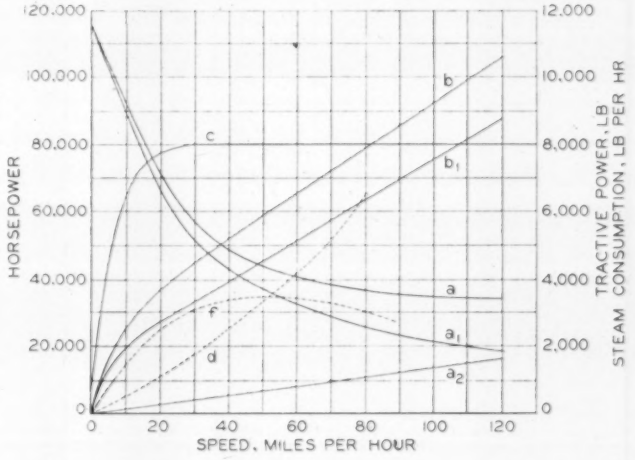


FIG. 1 PROBABLE PERFORMANCE CURVES OF HIGH-PRESSURE CONDENSING LOCOMOTIVE; 400,000 LB ON DRIVERS

(*a* total tractive power; a_1 engine tractive power; a_2 turbine tractive power; *b* total horsepower, turbine + engine; b_1 horsepower at drawbar (neglecting wind resistance); *c* steam consumption, including auxiliaries; *d*, *f*, refer to Fig. 2 of paper.)

Fig. 1, of this closure, graphically represents probable horsepower and tractive-power characteristics in relation to locomotive speed, which the author believes, are obtainable with the compounding arrangement described. A horsepower curve of a 4-6-4 locomotive from Fig. 2, of the paper, is shown in Fig. 1, of this closure, for comparison; also curve *d*, denoting the tractive requirements of a 1000-ton train on 0.5 per cent grade. The presentation refers to a condensing locomotive in general accordance with Fig. 1, of the paper, having 400,000 lb on drivers and a maximum boiler capacity, including auxiliaries, of 80,000 lb per hr.

The compounding arrangement described would also have an advantage in fulfilling the requirement for easy condensing conditions mentioned as (3), i.e., it is believed that the steam exhausted to the condenser with this arrangement would have a smaller heat content per pound than the one exhausted from a turbine, at the same back pressure. Fig. 2, presented herewith, is a Mollier diagram in which the author suggests how the expansion of steam in a turbine, from a pressure of 2000 psi abs and 900 F down to 17 psi abs pressure, might occur, and in which he contrasts therewith the expansion of the steam in a turbine, from the same steam pressure and temperature, to a receiver pressure of 150 psi, and from the latter pressure to 17 psi abs pressure in a uniflow engine.

Paradoxical as it may seem, the condensing problem on a locomotive then seems to the author to be in reality a problem in the design of boilers of prime movers and their power transmission. As far as the condensing means themselves are concerned, the author has well-

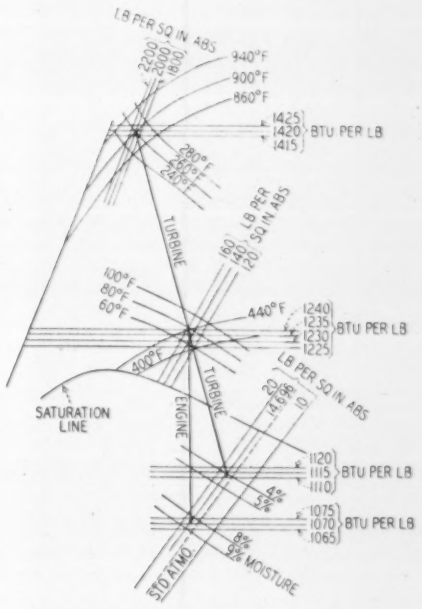


FIG. 2 MOLLIER DIAGRAM, SHOWING EXPANSION OF STEAM FROM 2000 PSI ABS AND 900 F DOWN TO 17 PSI ABS

founded hopes that some advance in the art will be made upon experimenting with injector condensers, and with the recooling of the water of condensation by air currents. Even if substantial thermal advantages do not result from such an arrangement, the use of an injector condenser, similar to an exhaust injector now used on locomotives, is likely to produce savings in weight as well as greater simplicity of operation and installation, compared with an air-cooled surface condenser.

A steam-generating pressure of 2000 psi at maximum working of the locomotive was assumed to be reached, when illustrating the heat drops in Fig. 2 of this closure. Though the use of such a high pressure may, offhand, appear to be a fantastic proposal, it seems to the author that it will not be too difficult to design a boiler plant with which such pressures can be safely produced. The high-pressure part of such a boiler plant would undoubtedly take the form of a forced-feed boiler of very small water contents, thereby involving less explosion risk than a moderate-pressure locomotive-type boiler; whereas, the low-pressure part, which would not carry more than the receiver pressure of say 150 psi, would be of the ordinary fire-tube type. It would have a large water-storage capacity and would serve as a steam accumulator as well as an economizer. The highest practical steam-generation pressure would, in such a system, be, in all likelihood, not so much dependent upon the art of building suitable boilers as it would be dependent upon the ability of the turbine manufacturers to build high-speed machines for such pressures. As regards the secondary expansion stage, it should be possible to utilize a valveless type of rotating uniflow engine, the development of which has already progressed to a gratifying degree.

The turbine and engine would revolve in one direction only, so that the reversal of the locomotive would have to be effected by a gear shift at standstill. Mr. Lipetz looks upon this as a serious problem. However, the author believes that, with an arrangement such as is contemplated for the type of drive truck shown in Fig. 1 of the paper, this problem can be satisfactorily solved.

By the foregoing concrete suggestions for an approach to the author's objectives, he hopes that Mr. Lipetz' doubts, as to the general possibilities of condensation on locomotives, may be somewhat allayed. Moreover, the author feels that, with his forecast of a substantially altered horsepower characteristic in Fig. 1, of this closure, the problem of fitting a locomotive design to various types of operation, which problem Mr. Lipetz dwelt upon in his discussion, will be considerably eased, for it seems entirely possible to adapt a locomotive of the general wheel arrangement, shown in Fig. 1 of the paper, to most efficient operation at various maximum speeds, by altering the gear ratio between the drive shaft and the driven axles, together with the proportions of the engine. In other words, whereas, the horsepower curve of Fig. 1, herewith, was calculated so as to obtain the maximum heat drop at 120 mph, it could have been calculated so that the maximum heat drop would have been reached at say 70 mph, without assuming a materially altered locomotive construction. The number of axles and their arrangement, the weight of the locomotive as a whole, and its distribution, and therewith its maximum tractive power, would remain practically unchanged for each given maximum horsepower output, no matter at what locomotive speed it was obtained; an unquestionable advantage for standardization. It is this advantage which the author had in mind when establishing objective 7, i.e., the one of obtaining low first cost and low cost of maintenance.

As to objective 5, dealing with the lowering of the center of gravity, the author agrees with Mr. Lipetz that there would be no object in lowering it more than necessary to insure safe operation on curves. However, the author has been informed in various instances that higher speeds on curves are being allowed for Diesel-electric locomotives, because of their low center of gravity, than are being allowed in the case of steam locomotives. The view seems to be generally accepted that a relatively low center of gravity in a vehicle offers a greater margin for safety than a relatively high one. It is also to be taken into consideration, in this connection, that it is more difficult to stay within this safe margin with present locomotives, when designing them for ultrahigh speeds and power outputs, than it would be in building them with general wheel arrangements, as in Fig. 1 of the paper. It is an added advantage of the latter design that the frame can be kept close to the rail between trucks, and that, therewith, greater building height for boilers, condensers, and auxiliaries is possible.

The author is indebted to Mr. Clark for the encouraging appraisal of his effort to interest locomotive designers in trying for the utilization of the greater thermal possibilities of steam, in view of their successful realization in steam power plants.

In conclusion, the author begs to call attention to an error in the text of the paper. In the third line of the last paragraph on page 1, "one hundred per cent" should be substituted for fifty per cent.

R. M. OSTERMANN.[5]

Solving Pipe Problems

COMMENT BY SABIN CROCKER[6]

About two years ago, the writer had the privilege of examining the "model flexibility analyzer," originated and built by the author of this paper,[7] in the basement workshop of his home. Not only does the design attest him to be a clever engineer, but the workmanship, demonstrated in building the analyzer, proves him to be a master craftsman as well.

Unusual precision of measurement is afforded through matching the needles of the adjustable micrometer head with corresponding needles on the floating head built on the free end of the model. In this ingenious device the adjustable head can be set to simulate the desired movement of the pipe line, and the free end of the model brought to it through loadings and moments applied by suspending weights on strings, using pulleys where needed for change in direction. Both the simplicity and the sensitivity of this device are noteworthy.

The author is to be commended also for a straightforward factual account of his own solution of a number of flexibility problems for which results obtained by other methods have been published. As shown by Tables 1 and 2 of the paper, reasonably good agreement exists between model-test results on the three-dimensional pipe line illustrated in the "Piping Handbook"[8] and the results of the graphoanalytical method given therein. A square-corner-chart solution of this problem also gives results in close agreement with the detailed solution in the handbook. Where bends have a radius approximately 5 times the pipe diameter, as in this problem, the arcs may be treated as square corners without serious error both when loaded in the plane of the bend and when subjected to side loading.

As pointed out by the author, discrepancies between accepted theory and test results for pipe bends have been called to

---

[5] Vice-President, The Superheater Company, Chicago, Ill. Mem. A.S.M.E.

[6] Senior Engineer, Engineering Division, The Detroit Edison Company, Detroit, Mich. Mem. A.S.M.E.

[7] "Solving Pipe Problems," by Fred M. Hill, MECHANICAL ENGINEERING, January, 1941, pp. 19–22.

[8] "Piping Handbook," by J. H. Walker and Sabin Crocker, McGraw-Hill Book Company, New York, N. Y., 1939.

attention on several occasions,[9] but so far no one has offered a rational explanation of the greater deflection found when forces and moments are applied at right angles to the plane of a pipe bend. Incidentally, the writer is under the impression that this discrepancy does not show up in the case of a solid curved bar. Perhaps the author can offer some evidence on this point from his experiments with wire models.

In considering these discrepancies it should be emphasized that the formulas given in the "Piping Handbook" agree in all essentials with those developed by Timoshenko,[10] Hovgaard,[11] de Jonge,[10] Marchant,[12] and others who have worked on three-dimensional pipe problems. All of these solutions give practically identical results.

The three-dimensional problem which probably has been solved the most times by different methods is that attributed to Professor Hovgaard in Table 3 of the paper. The reacting forces, determined from the model flexibility analyzer, are further compared with those found by the various analytical and graphical solutions in Table 1 of this discussion.

TABLE 1 COMPARISON OF REACTING FORCES HOVGAARD'S THREE-DIMENSIONAL PIPE-LINE PROBLEM[13]

	Forces		
	P	Q	N
Powell[14] (square corners)	1802	1834	627
Hovgaard[11] (1937 bends)	1726	1815	632
Piping Handbook[8] (graphoanalytical):			
Square corners	1799	1817	620
Bends	1714	1784	639
Elastic-point[15] (square corners)	1914	2062	699
Wert and Smith Charts[16] (square corners)	1840	1820	625
Hill model test	2010	2175	772

TABLE 2 STUDY OF PERCENTAGE DEVIATIONS

Reference	Tests referred to calculations, including flattening factor K: Arithmetic-mean deviation	Deviation of resultant force	Deviation of resultant moment	Tests referred to calculations, disregarding flattening factor K: Arithmetic-mean deviation	Deviation of resultant force	Deviation of resultant moment
Figs. 1 and 2, Tables 1 and 2 of paper	8.62	+ 3.92	— 3.10	27.69	—30.13	—29.55
Hovgaard[a] bend, Table 3	20.68	+18.15	+11.15	...	...	...
Karelitz-Marchant[b] bend, Table 4	20.98	— 5.56	—15.80	...	...	...
Fig. 4, Table 5, of paper	5.92	— 3.80	—11.50	...	...	...
Fig. 5, Point *A*, of paper	...	— 8.89	—16.23	...	— 7.46	—11.55
Fig. 5, Point *B*, of paper	...	—19.20	+12.48	...	— 9.99	+ 9.74
Fig. 5, Point *C*, of paper	...	+26.57	— 0.57	...	— 8.74	— 7.90
Average deviation	(14.05)	12.30	10.12	(27.69)	14.08	14.68

[a] Refer to footnote (13) of previous discussion. [b] Refer to footnote (12) of previous discussion.

It is evident that a square-corner graphoanalytical solution, or a chart solution where applicable, happens to be entirely satisfactory for a problem such as used in this comparison. In addition to the simple pipe runs in one plane mentioned by the author, it would seem that, for many three-dimensional problems, the model-test method would not possess time-saving advantages over mathematical methods.

The time required for a square-corner approximate solution of a three-element three-dimensional problem by the graphoanalytical method is in the neighborhood of 3 hours. A five-element problem may require 5 or 6 hours. Chart solutions[16,17] are available for three-element three-dimensional problems which reduce the labor to possibly 30 min. These chart solutions can be extended to structures of more than three elements by assuming hypothetical intermediate anchors, but the resulting forces and moments are quite different from the actual values. Such an expedient may, however, give sufficient assurance that adequate flexibility has been provided.

While recognizing the advantages of the model flexibility analyzer for the solution of three-ended pipe structures, such as shown in the author's Fig. 5, it is the writer's opinion that a square-corner graphoanalytical solution will be found entirely adequate for the majority of problems encountered in practical piping design. Only in exceptional cases involving three-ended structures, or where it is desired to approach the limits of allowable thrust or stress in a complicated structure, will it be found desirable to employ a model test even where such testing equipment is readily available. Where model tests are warranted, the Hill model flexibility analyzer would seem to offer attractive possibilities.

COMMENT BY D. B. ROSSHEIM,[18] A. R. C. MARKL,[19] AND L. C. ANDREWS[20]

The author's concise description of apparatus, developed by him for testing pipe models and, in particular, the documentation of the accuracy of results obtainable therewith form a valuable contribution to the growing literature on the evaluation of expansion forces in piping. While the mathematical treatment of this problem has made great strides over the last 10 or 15 years, engineers in the van of this advance have long ago come to the realization of the limitations of the analytical approach and so have been forced to turn their attention to model testing as the only practical solution for involved problems. Among others, the company with which the writers are associated has devoted time and effort over a period of years to the development of both calculation methods and model-testing equipment with gratifying success.

Judging from our own experience, we consider the accuracy of the author's results as entirely adequate and representative of what can be done with relatively simple testing apparatus. We observe that the author has gaged the accuracy of his results by the arithmetic-mean error in the forces and moments, as compared with calculations. Since the combined stresses are roughly proportional to the resultant of the moments and, indirectly, to the resultant of the forces, we prefer to use these as indicators of the practical accuracy of model-test results. This avoids placing undue emphasis on the smaller components which, in many cases, may actually experience sign reversals without

[9] Discussion by Arthur McCutchan, Trans. A.S.M.E., vol. 60, 1938, p. 596.

[10] Appendix to closure of paper, "Frictional Resistance and Flexibility of Seamless-Tube Fittings Used in Pipe Welding," by Sabin Crocker and Arthur McCutchan, Trans. A.S.M.E., vol. 53, 1931, FSP-53-17, p. 243.

[11] "Further Studies of Three-Dimensional Pipe Bends," by William Hovgaard, Trans. A.S.M.E., vol. 59, 1937, pp. 647–650.

[12] "End Reactions and Stresses in Three-Dimensional Pipe Lines," by G. B. Karelitz and J. H. Marchant, Trans. A.S.M.E., vol. 59, June, 1937, pp. A68-A74.

[13] "Stresses in Three-Dimensional Pipe Bends," by William Hovgaard, Trans. A.S.M.E., vol. 57, 1935, pp. 401–415.

[14] Method developed by R. C. Powell of the Pacific Gas and Electric Company, based on pamphlet, "L'Aptitude Elastique des Tuyauteries à Vapeur au point de vue Dilation," by Henri Carlier, A. Carlier-Hermant, 5 Rue des Eperonniers, Bruxelles, 1925.

[15] "Application of the Elastic-Point Theory to Piping Stress Calculations," by S. W. Spielvogel and S. Kameros, Trans. A.S.M.E., vol. 57, 1935, pp. 165–168.

[16] "Pittsburgh Piping Design Manual," by E. A. Wert, S. Smith, G. Sinding-Larsen, and G. W. Petrie, Jr., Pittsburgh Piping and Equipment Company, Pittsburgh, Pa., 1935. This does not take into account movement of turbine, which affects deflections to be absorbed to a minor extent in this example.

[17] "Design of Piping for Flexibility With Flex-Anal Charts," by E. A. Wert and S. Smith, Blaw-Knox Company, Power Piping Division, Pittsburgh, Pa., 1940.

[18] Mechanical Engineer, M. W. Kellogg Company, New York, N. Y. Mem. A.S.M.E.

[19] Assistant Mechanical Engineer, M. W. Kellogg Company, New York, N. Y.

[20] Model Test Engineer, M. W. Kellogg Company, New York, N. Y.

TABLE 3 COMPARISON OF CALCULATIONS BY WRITERS' COMPANY AND MODEL TEST BY AUTHOR[a]

	Point A			Point B			Point C		
	Calculation A, including factor K	Calculation B, assuming K = 1	Model test by author	Calculation A, including factor K	Calculation B, assuming K = 1	Model test by author	Calculation A, including factor K	Calculation B, assuming K = 1	Model test by author
Force P, lb	— 2474	— 2477	— 2326	+ 1975	+ 1891	+ 1885	+ 499	+ 586	+ 441
Force N, lb	— 3597	— 3379	— 3118	+ 2478	+ 1712	+ 1380	+ 1119	+ 1667	+ 1737
Force Q, lb	+ 632	+ 1142	+ 1009	+ 1593	+ 1906	+ 1660	— 2225	— 3048	— 2669
Resultant force, lb	4411	4343	4019	3547	3184	2866	2540	3523	3215
Deviation, per cent, compared									
with calculation A	0	— 1.54	— 8.89	0	— 10.23	— 19.20	0	+ 38.70	+ 26.57
with calculation B		0	— 7.46		0	— 9.99		0	— 8.74
Moment U, in-lb	+288312	+323400	+300009	— 71220	+ 99060	+195017	— 29712	— 9519	+ 41238
Moment V, in-lb	+ 18816	+167904	+122823	+311304	+325668	+372674	—127061	—137954	—112382
Moment W, in-lb	+861240	+779376	+688439	—298812	—291720	—255129	—106770	—121561	—120102
Resultant moment	908412	860352	760946	437345	448300	491943	168603	184117	169572
Deviation, per cent, compared									
with calculation A	0	— 5.29	— 16.23	0	+ .50	+ 12.48	0	+ 9.20	+ 0.57
with calculation B		0	— 11.55			+ 9.74		0	— 7.90

[a] Refer to Fig. 5 of paper.

affecting the utility of the results. A study of the accuracies determined by both methods is given in Table 2 herewith.

With respect to the system with three fixed ends, shown in Fig. 5 of the paper, an analytical solution offers no great difficulties and we have made check calculations by a method which will be published shortly by the writer's company in the form of a manual. We have assumed 5-ft radii for all bends and have made duplicate calculations, once with and once without the flattening factor, the results of which are compared, in Table 3 of this discussion, with the author's test results, showing very close agreement. We regret we have not found time to run parallel model tests on our own equipment.

COMMENT BY C. R. SODERBERG[21]

The proposed method for the experimental solution of problems of expansion forces in piping is a rational one which should be of great value. When conditions so demand, there should be no difficulty in making the model of tubing with an appropriate value of the Rt/r^2 ratio. This imposes a restriction in the choice of scale, but otherwise requires no modification of the procedure.

The agreement with the author's experimental results and the various calculations available in the engineering literature is disappointingly poor. The discrepancies cited, in Tables 2, 3, 4, and 6 of the paper, may not be serious in practical cases, but the model procedure will fail to gain universal acceptance unless these discrepancies can be more fully explained. Unless the discrepancies are due to direct errors in the calculated data, it is not clear why the experiments should deviate from calculations by amounts of the order of 20 to 50 per cent. The writer would like to comment on this.

Considering a plane piping system OA, Fig. 1 of this discussion, of which the free end O is subjected to forces F_x and F_y, the resulting displacements may be written

$$\left.\begin{aligned} \Delta x &= \alpha_{xx} \cdot F_x + \alpha_{xy} F_y \\ \Delta y &= \alpha_{yx} \cdot F_x + \alpha_{yy} F_y \end{aligned}\right\} \quad \ldots [1]$$

The elastic properties of the piping system are now given by the "influence factors" α_{xx}, $\alpha_{xy} = \alpha_{yx}$ and α_{yy}, which of necessity have a positive determinant. As soon as this system is known, any other system may be derived by ordinary axis transformation, or by the use of Mohr's circle, as shown in Fig. 2 of this discussion. By this construction, it is possible to show, for example, that a force F applied in a direction φ from the x axis will produce deflections along its own direction only.

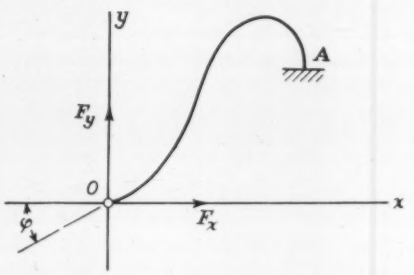


FIG. 1 PLANE PIPING SYSTEM

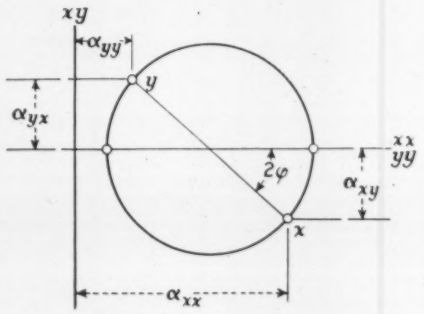


FIG. 2 DERIVATION OF SYSTEM BY USE OF MOHR'S CIRCLE

The accuracy by which these influence factors may be determined in any experimental setup depends upon their relative magnitudes. Those that have a small numerical value will have proportionately greater errors than those which are numerically large.

The practical piping problem is usually characterized by the fact that Δx and Δy are known, while F_x and F_y are unknown. This requires a solution of Equation [1], in terms of F_x and F_y which comes out as

$$\left.\begin{aligned} F_x &= \frac{\alpha_{yy}}{\alpha_{xx}\alpha_{yy} - \alpha_{xy}^2}\,\Delta x - \frac{\alpha_{xy}}{\alpha_{xx} \cdot \alpha_{yy} - \alpha_{xy}^2} \cdot \Delta y \\ F_y &= -\frac{\alpha_{xy}}{\alpha_{xx}\alpha_{yy} - \alpha_{xy}^2}\,\Delta x + \frac{\alpha_{xx}}{\alpha_{xx}\alpha_{yy} - \alpha_{xy}^2}\,\Delta y \end{aligned}\right\} \quad \ldots [2]$$

The elastic properties of the piping system are completely described by the influence factors, while the forces incidental to a certain set of displacements are of a more temporary significance. It is entirely possible that experimental errors inherent in the determination of the influence factors may be augmented by the mathematical process involved in the solution for the forces. This is true particularly when the determinant is small compared with the largest of the principal influence factors, that is, when one of the principal factors is very large and the other is very small. To establish the inherent accuracy of the experimental method, therefore, it would be advisable to compare the values of the influence factors obtained by experiment and by calculation, and then establish separately the degree to which these errors may be

[21] Professor of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Mass. Mem. A.S.M.E.

augmented by the succeeding mathematical process.

The foregoing discussion has been oversimplified by being restricted to two dimensions, but it serves to illustrate the fundamental possibility of augmentation of errors. It is actually a more serious matter in the general case when 6 variables and 21 influence factors must be taken into consideration.

It is unfortunate that the list of references did not include a paper by H. V. Semar,[22] covering a similar model arrangement used successfully in a number of cases.

COMMENT BY J. D. CONRAD[23]

For more than 3 years the writer's company has solved its more complicated three-dimensional pipe problems with model tests. This paper was therefore read with considerable interest by us. Our method of model testing has been presented in a paper by H. W. Semar.[22]

A brief comparison of methods is perhaps in order. Both methods solve the temperature-expansion problem by measuring the load-deflection relations in a scale model. The author has chosen to clamp one end of the model and to deflect the other end a given amount and direction by the application of three pure forces through lever arms, in such a manner that no rotation of this end of the pipe takes place. This condition is apparently obtained by a cut-and-try procedure both in regard to the magnitude of the three loads and the location of their attachment on the lever arm. With our method, we deflect one end of the pipe in the direction of free expansion by means of a slide which prevents any rotation at this end. The other end of the pipe is clamped in a frame which is prevented from both linear and rotational movement by six round-end pins. The force or rather change of force on each of these pins for a given pipe deflection is measured with a calibrated-spring arrangement. From these six pure forces can be calculated the end reactions and bending moments. As can be seen, this is a direct measurement of forces, and the change in each force can readily be obtained for several increments of pipe movement. The straight-line relationship which must exist between load and deflection immediately gives a check on the possibility of slippage at the pipe clamp, movement at any connection in the model, or permanent deformation in the model.

Two questions immediately arise concerning the author's method. Does he have any method of making this straight-line relationship check? Does the cut-and-try method of applying load not require a considerable amount of time and patience in order to get the needle points back in place for the deflected position of the pipe ends?

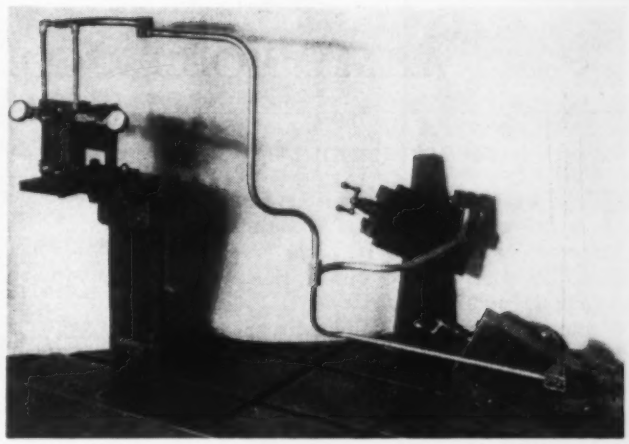


FIG. 3 SETUP OF TEST EQUIPMENT FOR SOLVING BRANCH-LINE-PIPE PROBLEM

The method developed by the writer's company, has been used for the solution of more complicated problems. A branch-line problem now in our laboratories is shown in Fig. 3 of this discussion. Here the addition of a second slide allows the same direct method of testing as is used in the two anchor lines. Again, we find ourselves asking just how much difficulty did the author experience in manipulating his apparatus for the branch line which he tested. Here, it would seem to be necessary to juggle the magnitude and position of six different forces with eight needle points to be brought into place.

We have also used our method for the solution of pipe lines with partial intermediate restraint, such as tie rods or springs. This we find quite easy to do with our setup. First we get the unrestrained motion at the desired point of application of such attachments. We then measure the effect of the pure force applied at this point and by superposition can obtain the final results. Has the author experimented along these lines with his method of testing and, if so, with what results?

AUTHOR'S CLOSURE

Mr. Crocker's complimentary remarks about the flexibility analyzer are appreciated. Regarding his impression that the discrepancy between accepted theory and test results does not exist in the case of solid bars used to stimulate bends with forces and moments applied at right angles to the plane of the bend, the author regrets that he cannot clear up this point at present due to changing employment and not having the necessary equipment at hand. The short time reported by Mr. Crocker for solving problems by the graphoanalytical method and by the use of charts speaks well for the degree of proficiency attained by the engineers of his company.

The author feels, however, that model methods will continue to gain in popularity, as evidenced by the announcement of Messrs. Rossheim, Markl, and Andrews in their discussion that their company has also developed a model method which gives very satisfactory results. A paper describing their methods and results should be a valuable contribution.

Professor Soderberg's comments to the effect that the agreement between the model answers reported by the author and those by calculation is "disappointingly poor" should be considered along with the fact that no field-test data are available from full-sized pipe runs. The author had hoped to gain information of this kind for use in the paper, but encountered overwhelming difficulties and was forced to abandon the idea.

Mr. Conrad asks whether slippage or permanent deformation can be detected in the author's analyzer method. This is accomplished rather simply by removing the loadings, resetting the micrometers to zero, and observing whether the free end of the model returns to the starting position. No trouble has been experienced in this respect.

In answer to his question, whether a large amount of manipulation is necessary to adjust the attached forces, the author has found that to a great extent the points of application can be determined quite closely with the hands before attaching the lines.

The determination of intermediate forces resulting from a restraint is accomplished by blocking the point in question, deflecting the free end, and then measuring the force necessary barely to free the model from the blocking.

F. M. HILL.[24]

---

[22] "The Determination of the Expansion Forces in Piping by Model Test," by H. W. Semar, Trans. A.S.M.E., vol. 61, 1939, pp. A21–A24.

[23] Mechanical Engineer, Steam Turbine Division, Westinghouse Electric & Manufacturing Company, Philadelphia, Pa. Jun. A.S.M.E.

[24] Manning, Maxwell & Moore, Inc., Boston, Mass. Mem. A.S.M.E.

A.S.M.E. BOILER CODE

Interpretations

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Anyone desiring information on the application of the Code is requested to communicate with the Committee Secretary, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are then sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and is passed upon at a regular meeting of the Committee.

This interpretation is later submitted to the Council of The American Society of Mechanical Engineers for approval after which it is issued to the inquirer and also published in MECHANICAL ENGINEERING.

Following is a record of the interpretations of this Committee formulated at the meeting of April 25, 1941, subsequently approved by the Council of The American Society of Mechanical Engineers.

CASE No. 842 (Reopened)

(Special Ruling)

Inquiry: Par. UA-23 states that the formulas for flanges are suggestive only and not mandatory. Recent developments in methods of flange design indicate that flexibility in some of the other paragraphs is desirable for the advancement of the art. Can modifications of these paragraphs be used in designing flanges forming parts of vessels stamped with the code symbol?

Reply: It is the opinion of the Committee that pending the adoption of revisions now being studied, the following paragraphs may be used and shall be considered as suggestive only and not mandatory: Pars. UA-19(*a*), UA-19(*e*), UA-19(*i*), UA-20, UA-22(*b*) (so far as the locating of reaction H_D and W is concerned), UA-22(*c*) (location of bolt reaction), UA-23(*a*) and UA-24(*d*) (2).

CASE No. 883 (Reopened)

For item (6) of reply change "7/8 in." to "3/4 in."

Revised Fig. 36

CASE No. 899

(Annulled)

CASE No. 928

(Special Ruling)

Inquiry: Case No. 920 provides for the welding of tube ends or weld necks to drums under specified conditions. In view of this interpretation, is it permissible to fusion weld superheater tubes, larger than the $2^1/_2$ in. diameter specified in Par. P-113, to manifolds or headers?

Reply: It is the opinion of the Committee that the $2^1/_2$ in. diameter limitation should now be removed and tubes of larger diameter may be fusion welded to headers under the provisions of Par. P-113.

CASE No. 929

(Special Ruling)

Inquiry: Is it permissible to use high-pressure high-temperature piping manufactured by the forging process if the pipe complies with Specification S-4, except that the chemical analysis, tensile strength, yield point, elongation, and heat-treatment meet the requirements specified for these items in Specification S-48, grade T-1?

Reply: It is the opinion of the Committee that such material will comply with the intent of the Code.

CASE No. 930

(Interpretation of Par. P-103)

Inquiry: Par. P-103(*a*) lists a number of specifications to which the materials used in the fabrication of fusion-welded drums, shells, or parts shall conform. There is no reference in this paragraph, or in any other part of the Code, to forged materials for which specifications and allowable stresses are given elsewhere in the Code. Is it permissible to fabricate forged headers and other pressure parts from materials conforming to Specifications S-8, S-50, and S-35?

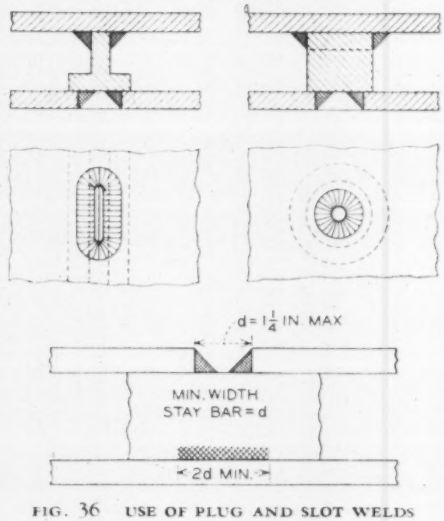


FIG. 36 USE OF PLUG AND SLOT WELDS FOR STAYING PLATES

Reply: It is the opinion of the Committee that forged materials for which specifications and allowable stresses are given may be used in the manufacture of pressure parts in accordance with the intent of Par. P-103(*b*), provided pressure and temperature limitations and other rules of the Code are complied with. Attention is directed to the limitations on the use of materials in accordance with Specification S-50 given in Pars. P-299(*a*) and UA-19(*g*).

CASE No. 931

(Special Ruling)

Inquiry: In view of the present emergency that makes it practically impossible to obtain certain materials made in accordance with Code specifications, may materials available in jobbers' stocks or elsewhere be used in Code boilers and other vessels?

Reply: It is the opinion of the Committee that, as a temporary expedient, material as covered by Specifications S-5, S-7, S-11, S-13, S-15, S-16, S-17, S-18, S-19, S-23, and S-24, but for which mill test reports or other evidence of compliance with the specifications are not available, may be used provided samples of such material are tested as to physical and chemical properties and shown to be in substantial compliance with the appropriate specifications applicable to the purpose for which the material is to be used, and the material shall be acceptable to the inspector.

Revisions and Addenda to Boiler Construction Code

IT IS the policy of the Boiler Code Committee to receive and consider as promptly as possible any desired revision of the rules and its code. Any suggestions for revisions or modifications that are approved by the Committee will be recommended for addenda to the code, to be included later in the proper place in the code.

The following proposed revisions have been approved for publication as proposed addenda to the code. They are published below with the corresponding paragraph numbers to identify their locations in the various sections of the code, and are submitted for criticism and approval from anyone interested therein.

It is to be noted that a proposed revision of the code should not be considered final until formally adopted by the Council of the Society and issued as pink-colored addenda sheets. Added words are printed in SMALL CAPITALS; words to be deleted are enclosed in brackets [ ]. Communications should be addressed to Secretary of the Boiler Code Committee, 29 West 39th St., New York, N. Y., in order that they may be presented to the Committee for consideration

PARS. P-103(*a*) AND U-71(*a*). Replace proposed revisions appearing in June, 1941, issue of MECHANICAL ENGINEERING, by the following:

(*a*) Material. The materials used in the fabrication of any fusion-welded drum, shell, or parts, covered by this Code shall conform to Specifications S-1, S-2, S-4, S-8, S-11, S-17, S-18, S-19, S-25, S-28 grade A, S-32, S-33, S-34, S-35, S-40, S-42, S-43, S-44, S-45, S-48, S-49, S-50, S-52, S-55, S-56, S-57, S-58, or S-60. The carbon content in all such materials shall not exceed 0.35 per cent.

PAR. P-299(*a*). Add the following:

Valves and other boiler appurtenances, such as water columns, may have fusion-welded joints provided the welding procedure and welding operator are qualified under the requirements of Par. P-112(*d*). No stress relieving, radiographic examination or inspection of the joint is required, but the manufacturer shall furnish, on request, a statement certifying that these requirements have been complied with.

PAR. P-299(*b*). Add the following to the proposed revision appearing in April, 1941, issue of MECHANICAL ENGINEERING:

Fittings in which there are minor changes in the center-to-face dimensions, or in which the angles of elbows differ from those given in the Standard may be considered to fall within the scope of these Standards provided the other rules for materials, dimensions, and thicknesses are met.

SPECIFICATIONS S-18, S-34, AND S-45. Specification S-18, in the Note preceding Par. 1, reference to A.S.T.M. Specifications A106 to be revised to read "A106-39." Specifications S-34 and S-45, it has been decided to drop the proposed revisions of these specifications as indicated in the April, 1941, issue of MECHANICAL ENGINEERING.

A.S.T.M. SPECIFICATIONS A240-40T for Corrosion-Resisting Chromium-Nickel Steel Sheet, Strip, and Plate for Fusion-Welded Unfired Pressure Vessels to be included in Section II of the Code as Specification S-62.

PAR. U-68(*b*). Replace the proposed revision of the second section, as published in the May, 1941, issue of MECHANICAL ENGINEERING, by the following:

When a drum has neither longitudinal nor circumferential joints, no test plate need be furnished for nozzles if the welding process and welding operator are qualified under Pars. UA-41 to UA-53.

THE STANDARD QUALIFICATION FOR WELDING PROCEDURE AND WELDING OPERATOR appearing in the Code will be revised to conform to the latest A.W.S. Qualification Procedure in so far as the applicable sections apply.

PAR. U-1(*a*). Replace the proposed revision appearing in the May, 1941, issue of MECHANICAL ENGINEERING by the following:

The rules in this section apply to unfired pressure vessels in which the diameter is over 6 in. and for internal or external pressures over 15 lb per sq in. All vessels however, irrespective of size or pressure, shall be equipped with safety devices in accordance with the requirements of this Code. Compliance with Par. U-65 (inspection) is not required for vessels of less than 5 cu ft capacity and also less than 250 lb working pressure, provided such vessels are stamped with the data required in Fig. U-10, except omitting the designated code symbol, and provided the welding process and welding operators are qualified in accordance with the requirements of this Code in the presence of an inspector qualified under the requirements of Par. U-65(*a*). Certificates shall be furnished for such noninspected vessels as shown in form no. U-1(*a*).

These exemptions apply to each single vessel and not to an assembly of vessels.

Vessels below these limits may be inspected and stamped with the Code symbol as provided in Pars. U-65 and U-66.

NOTE: Form no. U-1(*a*) will be a new form for noninspected vessels.

PAR. U-65(*b*). Add a second parentheses reading:

(For vessels not inspected (see Par. U-1(*a*)) use form no. U-1(*a*).)

TABLES P-7 AND U-2. Add the following stresses for Specification S-60 (A.S.T.M. Specifications A225-39T):

Plate Steels	Spec. Grade	Min. Tensile	Notes & Limita's.	−20 to 650	700	750
S-60	A	70000	(*)	14000	14000	14000
S-60	B	75000	(*)	15000	15000	15000

* Between temperatures of 750 to 1000 F, the stresses given herein for killed carbon steel, Spec. S-55, Grade B, may be used until high temperature test data becomes available.

Revise stress values for the following materials as follows:

KA2S MATERIALS:

Plate Steels
A.S.T.M. A167-39, Grades 304 & 308; 321, 347.

Pipe & Tubes
S-34, Grades P-8a and P-8b.
S-52, Grades T-8, T-18, and T-19.

Forgings
S-35, Grade F-8.

Castings
S-33, Grade C-9.

Bolting
A.S.T.M. A193-39T, Grade B-8;

Temperature F	S values	Temperature F	S values
−20 to 650	15000	950	12300
700	15000	1000	10000
750	14600	1050	8000
800	14300	1100	6000
850	14000	1150	4600
900	13400	1200	3600

KA2S MOLY MATERIALS:

Plate Steels
A.S.T.M. A167-39, Grades 316 and 317.

Tubes
S-52, Grade T-20.

Temperature F	S values	Temperature F	S values
−20 to 650	15000	950	12600
700	15000	1000	11200
750	14600	1050	9000
800	14300	1100	7000
850	14000	1150	5000
900	13400	1200	3600

Pipe and Tubes
S-34, Grade P-5a.
S-52, Grade T-5.

Temperature F	S values
800	11800
850	11200
900	10000
950	8000

Values at all other temperatures to remain as at present.

Pipe and Tubes
S-34, Grades P-3a, P-3b, P-11.
S-52, Grades T-3, T-11, T-12, T-14.

Temperature F	S values
800	11800
850	11200
900	10000
950	8000

Values at all other temperatures to remain as at present.

Pipe and Tubes
S-34, Grade P-5c.
S-52, Grade T-16.

Temperature F	S values
950	8000

Values at all other temperatures to remain as at present.

PAR. P-14. Revise to be identical to Par. U-14.

PAR. P-180 (*a*). Revise to read as follows:

(*a*) Where the thickness of the shell does not exceed 10 per cent of the inside radius, the maximum allowable working pressure on the shell of a boiler or drum [for temperatures not to exceed 650 F] shall be determined by the strength of the weakest course, computed from the thickness of the plate, [the tensile strength stamped thereon, as provided for in the specifications for the material] the efficiency of the longitudinal joint, or of the ligament between the tube holes in shell or drum (whichever is the least), the inside diameter of the course, [and the factor of safety.] AND THE MAXIMUM ALLOWABLE UNIT WORKING STRESS.

$$\left[\frac{TStE}{FSR}\right]\frac{StE}{R} = \text{maximum allowable working pressure, lb per sq in.}$$

where

[TS = ultimate tensile strength, lb per sq in., stamped on the shell plates or seamless shells as provided for in the specifications for the material,]

S = MAXIMUM ALLOWABLE UNIT WORKING STRESS, LB PER SQ IN. TAKEN FROM TABLE P-7,

t = minimum thickness of shell plates in weakest course, in.,

E = efficiency of longitudinal joints or of ligaments between openings,
for riveted joints = calculated riveted efficiency,
for fusion-welded joints = efficiency specified in Par. P-102,
for seamless shells = 100 per cent,
for ligaments between openings, the efficiency shall be calculated by the rules given in Pars. P-192 and P-193.

[FS = factor of safety, or the ratio of the ultimate strength of the material to the allowable stress]
[for new construction FS in the above formula = 5.]

R = inside radius of the weakest course of the shell or drum, in.]
[In a locomotive type boiler with a tapered course, the radius shall be the maximum in such course.]

(*b*) Where the thickness of the shell exceeds 10 per cent of the inside radius, the maximum allowable working pressure on the shell of a boiler or drum [for temperatures not to exceed 650 F,] shall be determined as in (*a*) by the following formula:

$SE\left[\frac{TSE}{FS}\right]\frac{(K^2-1)}{(K^2+1)}$ = maximum allowable working pressure, lb per sq in.

where $K = \frac{R+t}{R}$ or, ratio outside diameter to inside diameter.

Values of $\frac{(K^2-1)}{(K^2+1)}$ for given values of K may be obtained from Fig. P-9.

PAR. P-180 (*d*). To be deleted.

PAR. U-20 (*a*). Revise to read as follows:

(*a*) For Internal Pressure. WHERE THE THICKNESS OF THE CYLINDRICAL SHELL DOES NOT EXCEED 10 PER CENT OF THE INSIDE RADIUS, the maximum allowable working pressure on the shell of a pressure vessel shall be determined by the strength of the weakest course relative to the loads upon it computed from the thickness of the plate, the efficiency of the longitudinal joint, OR OF THE LIGAMENT BETWEEN OPENINGS (WHICHEVER IS THE LEAST), the inside diameter of the course, and the maximum allowable unit working stress.

The maximum a lowable working pressure for shells other than cylindrical, and for heads and other parts, shall be determined in a similar manner using the formulas appropriate for the parts, as elsewhere given in this code.

$\frac{StE}{R}$ = maximum allowable working pressure, lb per sq in.,
where
S = maximum allowable unit working stress, lb per sq in., taken from Tables U-2 and U-3,
t = minimum thickness of shell plates in weakest course, in.,
E = efficiency of longitudinal joints or of ligaments between openings,
for riveted joints = calculated riveted efficiency,
for fusion welded joints = efficiency specified in Pars. U-68, U-69, and U-70,
for seamless shells = 100 per cent,
for ligaments between openings, the efficiency shall be calculated by the rules given in Pars. P-192 and P-193 of the Power Boiler Code.

R = inside radius of the weakest course of the shell, in., [provided the thickness of the shell does not exceed 10 per cent of the radius. If the thickness is over 10 per cent of the radius, the outer radius shall be used.]

When a shell is made of any of the welded tubing or piping enumereted in Par. U-13(*e*), the factor SE shall be as given in Table U-2 (a).

(*b*) WHERE THE THICKNESS OF THE SHELL EXCEEDS 10 PER CENT OF THE INSIDE RADIUS, THE MAXIMUM ALLOWABLE WORKING PRESSURE ON THE SHELL SHALL BE DETERMINED AS IN (*a*) BY THE FOLLOWING FORMULA:

$SE\frac{(K^2-1)}{(K^2+1)}$ = maximum allowable working pressure, lb per sq in.

where $K = \frac{R+t}{R}$ or, ratio outside diameter to inside diameter.

Values of $\frac{(K^2-1)}{(K^2+1)}$ for given values of K may be obtained from Fig. U-1 1/2*.

* This will be the same as Fig. P-9.

REVIEWS OF BOOKS

And Notes on Books Received in the Engineering Societies Library

Technical Drafting

TECHNICAL DRAFTING. A text and reference book on graphics, by Charles H. Schumann. Harper & Brothers, New York, N. Y., 1940. Cloth, 6 1/4 × 9 1/4 in., 793 pages, 857 illustrations, 33 tables, and appendix, $3.50.

REVIEWED BY E. S. AULT[1]

ARRANGED to serve as a professional reference for engineers as well as a text for beginners, this book covers a wide range of topics. It is divided into two parts, the first of which presents the rules and practices of general engineering drawing; whereas, the second illustrates the application of these principles to the special practices of the separate engineering divisions. The special section on mechanical engineering is the longest. Combined with those on machine elements and welding it makes a total of 123 pages.

Even with the large size of the book the numerous topics included necessitate rather brief treatment of some of them. The discussion on the use of scales (a subject which is not appreciated by students) could well be extended and clarified. The indication of finished surfaces is hardly more than mentioned. The important subject of dimensioning is preceded by a short chapter on the materials and manufacture of machine parts. This is a very advisable arrangement but the treatment is too brief to be of much value. The treatment of dimensioning itself is more satisfying.

The theory of engineering drawing is presented successfully without the use of projection planes. For the more conservative a chapter on the old method is included.

Chapters on equipment, lettering, constructions, auxiliary views, intersections, pictorial drawing, perspective, and sketching are included. The beginner in mechanical engineering deserves more instruction and practice in technical sketching than is indicated in the text.

The chapter on mechanical-engineering drafting describes the various types of drawings and discusses commercial practice. The machine-elements chapter is limited almost entirely to gears.

In addition to other engineering classifications, the second part devotes chapters to shading, topographic drafting, graphs, duplication of engineering drawing, and the slide rule. Numerous tables of standards are included in an appendix.

When an author has to treat with so many topics he has the difficult duty of treating each one adequately, though briefly, and giving emphasis to each as it deserves. The author has succeeded in being brief, sometimes at the expense of adequacy. On the whole, the author has given his material proper relative emphasis, except as mentioned.

This book should have value to many engineers as a reference, and because of its division into general principles and specific application may have a special place in defense courses.

[1] Professor of Machine Design, Purdue University, Lafayette, Ind. Mem. A.S.M.E.

Books Received in Library

ANALYTICAL DESIGN OF HIGH-SPEED INTERNAL-COMBUSTION ENGINES. By F. M. Cousins. Pitman Publishing Corporation New York, N. Y., and Chicago, Ill., 1941. Cloth, 6 × 9 in., 226 pp., diagrams, charts, tables, $3.50. Beginning with a brief review of thermodynamic cycles the author proceeds to a detailed study of the dynamics of high-speed engines. In-line, V-type, radial, and offset cylinder engines are all considered in the discussion of engine balance and the analysis and design of cams, crankshafts, etc. For practical purposes, the analysis has been restricted to the calculus and simple harmonic theory. A bibliography are provided.

APPLIED HEAT TRANSMISSION. By H. J. Stoever. McGraw-Hill Book Co., Inc., New York, N. Y., and London, England, 1941. Cloth, 6 × 9½ in., 226 pp., illus., diagrams, charts, tables, $2.50. The purpose of this book is to provide in readily usable form some of the more important data on heat transmission and to describe some of the common types of equipment for transferring heat and kinds of insulation used in industry. The presentation is a thoroughly practical one, intended for engineers. A large number of charts and tables for determining convection coefficients and values of the pressure drop are included.

CAR BUILDERS' CYCLOPEDIA OF AMERICAN PRACTICE, Fifteenth edition, 1940. Compiled and edited for the Association of American Railroads, Mechanical Division. Edited by R. V. Wright and others. Simmons-Boardman Publishing Corporation, New York, N. Y. Cloth, 8 × 12 in., illus., diagrams, charts, tables, $5. This standard reference book presents definitions and typical illustrations of railroad and industrial cars, their parts, and equipment. There are also descriptions and illustrations of shops and equipment employed in car construction and repair. Many new designs of cars and appliances have been added since the previous edition, and the table of contents and index to car parts have been amplified for better reference.

COMMERCIAL REFRIGERATION AND COMFORT COOLING. By S. C. Moncher. Nickerson & Collins Co., Chicago, Ill., 1940. Cloth, 6 × 9½ in., 109 pp., illus., diagrams, charts, tables, $1.50. A brief, nonmathematical description of commercial refrigeration, with emphasis on engineering methods in common use. The book is intended for those with a general knowledge of the field, who wish definite information upon equipment and its installation. The book is confined to the type of apparatus used in retail shops and restaurants. Air conditioning is considered briefly.

CUTTING TOOLS FOR METAL MACHINING. By M. Kurrein and F. C. Lea. J. B. Lippincott Company, Philadelphia, Pa., and New York, N. Y., 1940. Cloth, 6 × 9 in., 219 pp., illus., diagrams, charts, tables, $6. This new and informative book describes how the best results can be obtained from any machining operation. Workshop practice, or production as distinct from design, is the major consideration. Tool shapes and angles are treated fully, and much recent information on feeds and speeds has been summarized. Tool grinding and hardening are also briefly covered.

ENGINEERING KINEMATICS. By A. Sloane. The Macmillan Co., New York, N. Y., 1941. Cloth, 6 × 9½ in., 310 pp., illus., diagrams, charts, tables, $4. Intended for use as a college course to fit in between the principles of applied mechanics and machine-design practice, this textbook discusses thoroughly the fundamentals of displacement, velocity, and acceleration as the common background of all mechanisms. The various types of mechanisms are used as illustrations of basic principles and as a source of practical problems.

GENERATING STATIONS, Economic Elements of Electrical Design. By A. H. Lovell. Third edition. McGraw-Hill Book Co., Inc., New York, N. Y., 1941. Cloth, 6 × 9 in., 471 pp., illus., diagrams, charts, tables, maps, $4.50. The application of economic principles to the problems of the design of generating stations and transmission systems is described. The selection and application of apparatus, the proportioning of details of the assembly, the balancing of initial and subsequent costs, and related topics are considered. The new edition has been revised in the light of recent developments. Illustrative problems accompany each chapter.

Great Britain. Department of Scientific and Industrial Research. Building Research. Wartime Building Bulletin No. 12. EMERGENCY PIPE REPAIRS. His Majesty's Stationery Office, London, England, 1941. Paper, 8⅓ × 11 in., 8 pp., charts (obtainable from British Library of Information, New York, N. Y., $0.15). This pamphlet tells what is known both of thoroughly tried methods alternative to lead jointing and of others of a less established nature which may be used to restore service quickly when pipe lines are injured by enemy action.

Great Britain. Home Office. Air-Raid Precautions Department Air-Raid Precautions Memorandum No. 1 (Second edition). ORGANIZATION OF AIR-RAID CASUALTIES SERVICES. 32 pp., $0.15. Air-Raid Precautions Memorandum No. 3 (Second edition). ORGANIZATION OF DECONTAMINATION SERVICES. 12 pp., $0.05. Air Raid Precautions Memorandum No. 6 (Second edition). LOCAL COMMUNICATIONS AND REPORTING OF AIR RAID DAMAGE. 49 pp., $0.15. Air Raid Precautions Memorandum No. 7 (First edition). PERSONNEL REQUIREMENTS FOR AIR RAID GENERAL AND FIRE PRECAUTIONS SERVICES, AND THE POLICE SERVICE. 11 pp., $0.05. His Majesty's Stationery Office, London, 1938–1939. Paper, 6 × 9½ in., diagrams, charts, tables (obtainable from British Library of Information, New York, N. Y.). These memoranda have been prepared for the guidance of local authorities in organizing services to deal with the problems that result from air raids.

Great Britain, Ministry of Health, Ministry of Home Security. RECOMMENDATIONS OF LORD HORDER'S COMMITTEE REGARDING THE CONDITIONS IN AIR-RAID SHELTERS WITH SPECIAL REFERENCE TO HEALTH; and a brief statement of action taken by the Government thereon. His Majesty's Stationery Office, London, 1940. Paper, 6 × 9½ in., 7 pp. (obtainable from British Library of Information, New York, N. Y., $0.05). These recommendations deal with various phases of the air-raid shelter problem, but are mainly concerned with sanitation, first aid, ventilation, and other hygienic considerations. Annotations describe what is being done to comply with the recommended practices.

HEATING, VENTILATING, AIR-CONDITIONING GUIDE, Vol. 19, 1941. American Society of Heating and Ventilating Engineers, New York, N. Y. Cloth, 6 × 9 in., 1120 pp., illus., diagrams, charts, tables, $5. The annual revision of this comprehensive manual provides designers and installers of apparatus for heating, ventilating, and air conditioning with up-to-date information on the subject. The theory and practical application presented cover both domestic and industrial practice. In addition to necessary revision the chapters have been rearranged and grouped into seven major sections. The Guide also contains a Catalog Data section.

HYDRAULIC MEASUREMENTS. By H. Addison. John Wiley & Sons, Inc., New York, N. Y., 1941. Cloth, 5½ × 9 in., 301 pp., illus., diagrams, charts, tables, $5. This is a manual of hydraulic measuring technique, intended to be of practical utility both in the laboratory and in making measurements under service conditions. The whole range of measurements is covered, and a great variety of methods and apparatus is considered critically. A glossary and a bibliography are appended.

INDUSTRIAL RELATIONS DIGESTS. I—The Organization of a Personnel Department. 7 pp. II—The Employment Division. 7 pp. III—Reorganization of Hour Schedules. 7 pp. Princeton University, Industrial Relations Section, Princeton, N. J., 1941. Paper, 7 × 10 in., tables, $0.20 each. The three pamphlets listed have been prepared for use in companies facing rapid expansion because of defense orders. They are based on information received currently from a large number of representative companies. In the case of No. III, a more complete study is in preparation.

DER KORROSIONSSCHUTZ METALLISCHER WERKSTOFFE UND IHRER LEGIERUNGEN. (Die Korrosion Metallischer Werkstoffe, Band 3.) Edited by O. Kröhnke and G. Masing. S. Hirzel, Leipzig, Germany, 1940. Paper, 7 × 10 in., 615 pp., illus., diagrams, charts, tables, 47.50 rm. This volume provides a comprehensive review of the methods used to protect metals against corrosion. An introductory general discussion of the problem and of the methods of protection that are available is followed by detailed discussions of the preliminary treatment of iron and steel, and by sections on paints and lacquers, bituminous coatings, plastics, enamels, phosphate processes, coloring processes, electroplating and oxide films on aluminum. A number of specialists have collaborated in preparing the treatise.

KUPFER IM TECHNISCHEN EISEN. (Reine und angewandte Metallkunde in Einzeldarstellungen, Vol. 4.) By H. Cornelius. Julius Springer, Berlin, Germany, 1940. Cloth and unbound, 6 × 9½ in., 225 pp., illus., diagrams, charts, tables, 28.50 rm.; unbound, 27 rm. The two parts of this work deal respectively with copper in steel and copper in cast iron. The author discusses the structure and physical properties of copper-containing ferrous materials, the influence of copper on working properties and the special purposes for which these alloys are adapted. The influence of precipitation-hardening on the properties of copper steels is considered, and the cast-iron section includes chapters on copper in malleable cast iron and chilled castings.

MANUAL OF A.S.T.M. STANDARDS ON REFRACTORY MATERIALS, prepared by A.S.T.M. Committee C-8 on Refractories. American Society for Testing Materials, Philadelphia, Pa., January, 1941. Cloth and board, 6 × 9 in., 174 pp., illus., diagrams, charts, tables, board, $1.50; cloth, $1.75. All of the A.S.T.M. specifications, classifications, methods of testing, and definitions pertaining to refractories are brought together in convenient form. Certain other pertinent information, of value in the testing and use of refractories, is also included, such as recommended procedures, standard sampling for chemical analysis, and industrial surveys of service conditions. The personnel and regulations governing the A.S.T.M. refractories committee are appended.

A.S.M.E. NEWS

And Notes on Other Engineering Activities

Louisville, Center of Seething Industrial Area, Host for A.S.M.E. Fall Meeting

LOUISVILLE, the "Gateway of the South," will be host at the A.S.M.E. Fall Meeting, October 12–15. Besides a challenging technical session, plans for which are rapidly nearing completion, Louisville offers itself as the center of a seething industrial area, stimulated by national defense and a rapid rise in population. It graciously combines the charm of the South with the bustle of the North.

"Fast horses, good whiskey, and pretty women" has long been a phrase associated with the Bluegrass State, but its huge industrial capacity is now a major cog in the national-defense machine. The du Pont engineered powder plant and the Goodyear bag-loading plant at Charlestown, Indiana, largest in the world, is twelve miles away. Here 27,000 workmen and $93,000,000 are producing a plant to make 600,000 pounds of powder a day.

Fort Knox, center of the mechanized cavalry and largest in the country, is forty miles to the south. Here they will test ballistically the huge guns to be assembled at Louisville's Naval Gun Mounting Plant, now being built by Westinghouse. Fort Knox is also the world's greatest storehouse of gold bullion. The huge gold vault will be one of the many points of interest on an excursion trip to the Fort.

Has Varied Industries

Peacetime pursuits of Louisville present an unusual cross section of the industrial world. Here more than 12 billion cigarettes are produced annually, and over 40 per cent of the nation's whiskey. Textile and woolen mills comprise a major industry of the city along with metal products such as boilers, farm implements, welding fittings, and valves.

Natural beauty and historical spots abound throughout the Louisville area. Mammoth Cave with all its inspiring beauty, one of the seven wonders of the world, is located 100 miles to the South. Lincoln's birthplace and shrine at Hodgensville and My Old Kentucky Home at Bardstown are visited annually by thousands.

Home of George Rogers Clark

Louisville is connected with early American history by two outstanding ties. It was founded by George Rogers Clark when he established military bases at the falls of the Ohio River in the conquest of the British. His remains rest in beautiful Cave Hill Cemetery, a high light in a sight-seeing tour of Louisville. The tomb of Zachary Taylor, twelfth president of the United States, is located on the grounds of the ex-President's home near the city limits.

Louisville is famous for its 2056 acres of parks which are conceded to be the most beautiful civic natural parks of America.

Many of the interesting spots in and near Louisville will be included in excursion trips for both members, friends, and wives. Churchill Downs, scene of the famous Kentucky Derby and noted for its landscape gardening, will be one of the points of interest.

Plant trips have already been scheduled to a large cigarette-manufacturing plant where a tobacco auction will be held, a visit to witness a new-type electrical precipitator in action, and a trip through one of Louisville's famous distilleries where refreshments will be served.

Many of the technical papers will deal with subjects that will tie in with the plant trips.

Louisville is eighty-three miles from the country's center of population and is served by trunk lines of railroad, bus, and airplane.

With all these attractions for visitors and with an unusual technical session promised, Louisville looks forward to one of the most interesting and instructive sessions in the history of the A.S.M.E.

Louisville Convention League

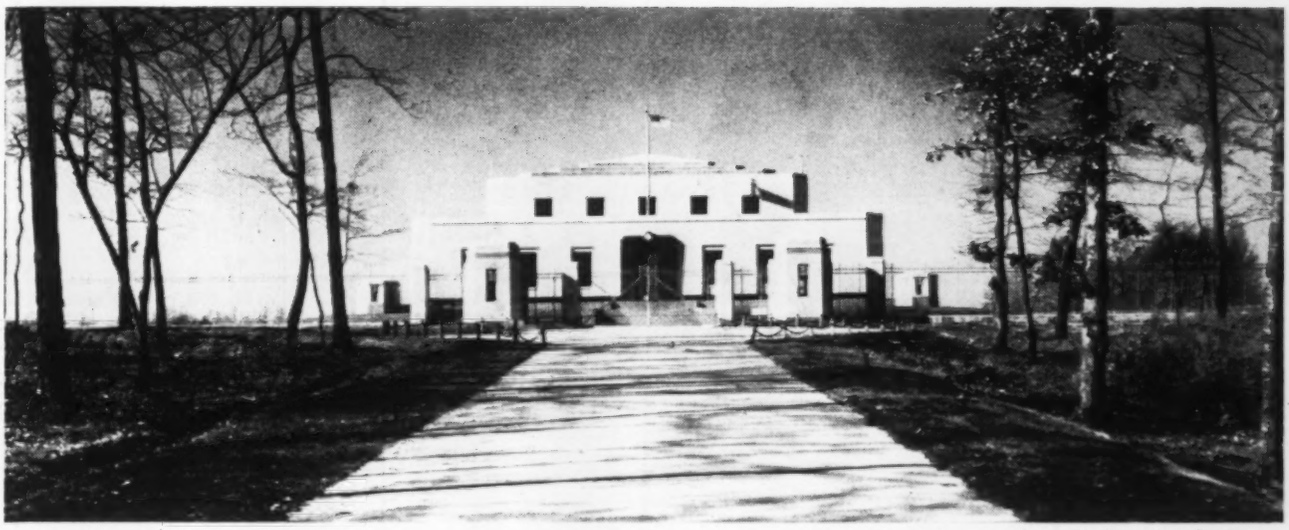
BLUEGRASS HORSE FARMS NEAR LOUISVILLE, KY.

A.S.M.E. Officers Are Nominated for the Coming Year

Members of the A.S.M.E. Nominating Committee for 1941, A. L. Kimball, chairman, N. C. Ebaugh, secretary, W. F. Thompson, E. J. Billings, H. B. Joyce, R. E. Turner, Earl Mendenhall, and L. J. Lassalle have nominated as directors of the Society for 1941 the following:

Office	Nominee
President	James W. Parker
Vice-Presidents	Clarke F. Freeman
	Clair B. Peck
	William H. Winterrowd
	Willis R. Woolrich
Managers	William G. Christy
	H. L. Eggleston
	T. S. McEwan

Biographical sketches of the candidates for office will be published in the August issue of MECHANICAL ENGINEERING.



Louisville Convention League

THE UNITED STATES GOLD DEPOSITORY AT FORT KNOX, KY., WILL BE A POINT OF INTEREST ON ONE OF THE INSPECTION TRIPS DURING THE A.S.M.E. FALL MEETING AT LOUISVILLE, KY.

A.S.M.E. Program of Cooperation Between Research Committee and Divisions Under Way

THE response of the Research Committee of The American Society of Mechanical Engineers to the inauguration of a special group of research secretaries of the professional divisions was reported at a meeting of the committee held on April 18, 1941. Announcement of the research-secretary plan was made in a report of the committee published in the March, 1941, issue of MECHANICAL ENGINEERING, pages 200 to 202.

Five Divisions Represented

E. G. Bailey, chairman of the Research Committee, reported that in response to an invitation, five of the professional divisions had been represented by their research secretaries, or other persons, at a conference on furnace radiation. At this conference it had been agreed that the Society should sponsor a new special research committee whose scope should cover a field broad enough to include furnace radiation and the behavior of ash and slag. Mr. Bailey expressed himself as being well pleased with the cooperation of the divisions and their research secretaries.

Louisville Convention League

MY OLD KENTUCKY HOME AT BARDSTOWN, KY., NEAR LOUISVILLE

(Where Stephen Collins Foster was inspired to write the famous song of the same name.)

Mr. Bailey reported also that the Heat Transfer Division, through its research secretary, had notified the Research Committee of a problem that the Society might be asked to sponsor. It will be recalled that the committee's report, previously referred to, had stated that one of its functions was to give consideration to research projects suggested by the divisions. The case reported by Mr. Bailey illustrates the practicability of such a relationship between two Society groups.

A third case of cooperation between the committee and the divisions was reported by Mr. Bailey as being a proposed joint session at the 1941 Annual Meeting to be sponsored by the committee and the Power, Fuels, and Heat Transfer Divisions.

All Members Free to Make Suggestions

Cooperation between the Research Committee and the Local Sections came to the notice of the committee through an action of the 1940 Group Delegates Conference which suggested that the Research Committee be requested "to devise and publish procedures for the operation of A.S.M.E. Local Section research committees, whose purpose would be to aid and supplement the standing committee in the conduct of projects, the collecting of information, the soliciting of papers, and the soliciting of funds." Discussion in the Research Committee centered around the fact that every member of the Society is free at all times to make suggestions to the Research Committee; and at a meeting of the Board on Technology, held on April 24, it was further pointed out that such assistance as the delegates suggested that the local sections be organized to render to the Research Committee could be directed, as occasion demanded, by the sections' executive committees.

Franklin Institute Medals to A.S.M.E. Members

ON May 21, medal day of The Franklin Institute, Philadelphia, Pa., the following A.S.M.E. members were among those honored.

BENJAMIN JAMES WILSON, chief, mechanical division, Research Department, Leeds and Northrup Company, Philadelphia, received the Longstreth Medal.

WILLIS H. CARRIER, chairman of the Board, Carrier Corporation, Syracuse, N. Y., the Brown Medal. (First award of Brown Medal.)

JOHN M. LESSELLS, technical editor, the *Journal of Applied Mechanics*, and CHARLES W. MACGREGOR, both associate professors of mechanical engineering, Massachusetts Institute of Technology, Cambridge, Mass., the Levy Medal.

EDWIN H. ARMSTRONG, professor of electrical engineering, Columbia University, New York, N. Y., the Franklin Medal and a certificate of honorary membership. (Major Armstrong is an A.S.M.E. member, but he received the Society's Holley Medal in 1940.)

Alfred P. Sloan Fellowship to A.S.M.E. Junior

ONE of the eleven young industrial executives, nominated by industries in all parts of the United States and awarded Alfred P. Sloan Fellowships for an intensive one-year cooperative program of executive development in business administration and economics at the Massachusetts Institute of Technology, is William G. Duvall, chief of the training and research section of the Western Electric Company, Baltimore, Md. Mr. Duvall is a junior member of A.S.M.E.

AT THE BANQUET OF THE A.S.M.E. OIL AND GAS POWER DIVISION, FRIDAY, JUNE 13

National Meeting of A.S.M.E. Oil and Gas Power Division Features Progress in Diesel Operation

THE Hotel President, Kansas City, Mo., was the headquarters of the Fourteenth National Meeting of the Oil and Gas Power Division of The American Society of Mechanical Engineers, which opened on Wednesday, June 11, and continued through the remainder of the week.

A preliminary program of the meeting appeared in the June issue of MECHANICAL ENGINEERING. Included with the usual features of such meetings—technical sessions, social events, visits to neighboring industries and plants, and the exhibit of engines and accessories which has always run in parallel with the sessions—was a "Diesel Quiz" in which members of the audience were given an opportunity to stump the experts.

In line with the practice of the Division each registrant was provided with copies of the papers to be presented, and will receive at a later date, when the discussion has been made available, another set of the "proceedings" which will be covered by the registration fee. A number of the papers are scheduled for publication in MECHANICAL ENGINEERING and Transactions.

Through the energy and courtesy of L. N. Rowley, Jr., secretary of the Executive Committee of the Division, the following high lights of the technical sessions have been made available.

Technical Papers Stimulate Discussion

Layout, design, and construction of foundations for vertical Diesel engines rank high in importance among the factors essential to successful operation. First step in the design is a study of the general features of the area around the installation (proximity, construction, and use of surrounding structures, possibility of interference with other operations in the same building) according to Kenneth H. Larkin, Burns & McDonnell Engineering Co., Kansas City, Mo. Definite knowledge of the foundation soil, as determined by auger borings, is likewise important. Having explained the nature and characteristics of engine vibrations, Mr. Larkin outlined methods used in engine design to eliminate or reduce vibration.

Two aspects of engine maintenance were covered in related papers: "Internal-Combustion-Engine Casualty Experience," by H. J. Vander Eb, Hartford Steam Boiler Inspection and Insurance Co., and "Inspection Procedures and Instruments for Diesel Engines," by E. R. Spencer, The Cooper-Bessemer Corporation. Before presenting data on accident experience on approximately 75 per cent of the insured engines, Mr. Vander Eb pointed out that engine installations must meet certain requirements as to manufacture, condition, freedom from overloads, nature of cooling-water system, competence of operators, and provision of essential controls and instruments. He also carefully explained the definition of "accident," according to insurance usage.

The paper on inspection procedures should have special value to operators as the author presented a complete picture of the methods to be used in checking an engine's condition and gave recommended allowances for wear, misalignment, and deformation. Although the time allowed between inspections depends on load factor, nature of fuel, frequency of starting and stopping, operating conditions, program of running repairs, and lubrication, Mr. Spencer suggested 8000 to 10,000 hours between inspection and overhaul as a good average figure for heavy-duty slow-speed engines.

In a session devoted to supercharging, J. B. Harshman, Stanolind Pipe Line Co., described operating experiences with Büchi exhaust turboblowers for supercharging four-stroke-cycle air-injection engines in pipe-line service. After a résumé of the history and general methods of supercharging, Mr. Harshman presented considerable experience data on the Büchi equipment installed on several engines of the Stanolind system. On the basis of this experience he concluded that use of supercharging to increase the horsepower of existing pipeline engines was not only practicable but economically justifiable. Supercharging a 500-hp engine gave 250 hp additional capacity at a cost of about $50 per hp, including new gears for increasing the speed of the pump. This compares with a cost of about twice as much per installed hp for additional pumping units. Supercharging is also useful on pipe-line service for handling temporary peak loads.

Results of tests comparing an engine fitted for underpiston supercharging, used in Europe but not previously tried in this country, and a trunk-piston engine of nearly identical output, were reported by E. S. Dennison and W. A. Morain, Electric Boat Co. Using the under side of the piston as an air compressor makes it possible to supercharge without use of external accessories and effects a valuable saving in space. However, the crosshead construction necessary is relatively costly and the authors made no claims as to the economic advantages of such a unit for general purposes. The unit tested and a similar unit built later have seen several months of satisfactory service.

Experiments made by B. H. Jennings, North-

H. L. CRAIN, CHAIRMAN, KANSAS CITY SECTION, WELCOMES OIL AND GAS POWER DIVISION

western Technological Institute, and T. E. Jackson, Lehigh University, indicate that measurement of the pressure existing just before exhaust in a Diesel engine may be used to determine the distribution of load among the cylinders of a multicylinder engine and so may be used to make operating adjustments. After pointing out disadvantages of existing methods, such as use of conventional indicators on slow-speed engines, comparisons of exhaust-gas temperatures, or examination of exhaust color and appearance, the author explained the theory behind the suggested use of pre-exhaust temperature and presented test data showing that under known conditions of injection, timing, and compression ratio, it was possible to evaluate both indicated and brake horsepower in terms of pre-exhaust pressure. Experimental work in progress shows the same method to be applicable to spark-ignition engines.

By means of a theoretical analysis, C. W. Good, University of Michigan, showed that the power loss accompanying combustion knock may be attributed to a mass vibration of the gas within the combustion chamber, rather than to radiation, as has been supposed. The analysis also indicates that the loss with the Diesel cycle is relatively less than with the Otto cycle.

Methods for purifying lubricating oil, and fuel oil where necessary, were discussed at another session. Use of centrifuges for this purpose was described in a paper by C. W. Bryden, De Laval Separator Co.; in Mr. Bryden's absence the paper was read by D. A. Gardner of the same company. The author told of early applications of centrifuging to oil purification, pointed out methods of operation to insure best results, cited the advantages of centrifugal purification, and gave representative cost figures.

In a companion paper, W. C. Bauer, Briggs Clarifier Co., discussed use of adsorbent filters for continuous maintenance of lubricating oil. He began by explaining the significance of tests used to describe the condition of a lubricating oil and continued with test data comparing adsorbent filters of the molded cartridge type with various competitive units.

Other papers presented at the meeting included "Instrumentation Used in Development and Testing of Diesel Engines," by C. R. Maxwell and K. M. Brown, Caterpillar Tractor Co.; "Hydraulic Characteristics of Fuel Injection Nozzles," by O. F. Zahn; "Chrome-Plating of Cylinder Bores," by H. Van der Horst, Van der Horst Corp. of America; "Application of Compression-Ignition Oil Engines to Aviation," by V. L. Maleev, Oklahoma A.&M. College; and "Instruments and Automatic Control Apparatus for Diesel Engines," by W. H. Sisson, Minneapolis-Honeywell Regulator Co.

"Mixer" and "Quiz" Successful

The untiring efforts of an unusually active and effective local committee made the meeting an outstanding success socially. A "Mixer" on Wednesday evening started the ball rolling. Designed to break the ice and to promote acquaintanceship, the program featured an informal cabaret atmosphere with a group of strolling troubadours providing music and entertainment during the dinner hour. Dancing and general good fellowship rounded off the evening.

Even though handicapped by the unavoidable absence of C. G. A. Rosen, master of ceremonies, the Diesel Quiz on Wednesday evening drew more than 200 and proved hilariously successful. Not only did the experts answer questions; the audience was drawn into the melee and some of the wittiest replies came from the crowd. C. E. Beck and W. L. H. Doyle alternated in the arduous role of master of ceremonies. The board of "experts" included E. R. Spencer, E. J. Kates, C. W. Good, and P. B. Jackson. They were ably assisted by Ted Gupton, J. H. Galloway, S. A. Hadley, V. L. Maleev, H. E. Degler, L. T. Brown, and other "experts" from the audience.

An elaborate program of entertainment marked the banquet held Friday evening. After C. E. Beck, as toastmaster, had disposed of the formalities on a split-second schedule, Tom Collins, Sunday editor of the *Kansas City Journal*, presented his humorous dissertation on "Luck—Its Care and Feeding." Dancing followed a one-hour floor show. Ladies were presented with corsages and an appropriate souvenir of the occasion.

Election of Officers

At the meeting members of the Executive Committee of the Oil and Gas Power Division were elected, as well as associate members.

Their names follow:

Executive Committee: W. L. H. Doyle, *Chairman*, E. S. Dennison, C. W. Good, H. E. Degler, E. J. Kates, and L. N. Rowley, Jr., *Secretary*.

Associates: F. G. Hechler, L. H. Morrison, B. V. E. Nordberg, R. D. Campbell, M. M. Dana, C. E. Beck, M. J. Reed, G. J. Dashefsky, W. K. Gregory, G. C. Boyer, P. B. Jackson, and Lee Schneitter.

Changes in Wood Finishes and Finishing Methods Resulting From Raw-Material Shortages

Relation to the National-Defense Program

AT A recent meeting the Committee on Wood Finishing of the Wood Industries Division of the A.S.M.E. discussed materials used in industrial finishing in relation to their availability for the production of civilian goods during the current national-defense program. A survey was made to emphasize the necessity for studying raw materials to determine which materials are on government priority lists, or critical lists, which may become priority lists, so that substitute formulations can be considered. It is not the purpose or intention of the committee to be specific as to materials or substitutions because of the ever-changing availability of the materials which are in either the priority or critical classifications. For example, a material may be on the priority list at the present time, but, because of expanding production facilities, an adequate supply might be available for all needs in a few months. Other materials which are available for all possible demands at the present time, in the event of their increased use as substitutes for materials which are no longer available, may soon become scarce and subject to priorities. Lead may be an example of such a material.

Materials to Be Considered for Substitutions

In general, any materials which must be transported to this country by ocean-going vessels are critical and should be considered for possible substitution. Other classes which are likely to be unavailable include those materials needed for defense or war, many of which are already on priority lists or on a critical list which is subject to priority ratings at any time. In addition, there are materials to be considered, the manufacture of which interferes with the production of defense or war materials, e.g., formaldehyde. Finally, because of the increasing shortage of truck and railroad transportation, consideration must be given to the materials which require transportation in large quantities for long distances. It is apparent, therefore, that the ideal substitute for any material which is unavailable should be a domestic material, the manufacture of which does not interfere with national defense, and which is available at a short distance from the place of consumption.

The following lists include some of the materials for wood finishing which should be considered for possible substitution. Those on the priority list are, of course, already practically unavailable except through the use of priority ratings. Supplies of materials on the critical list are dwindling rapidly and consequently they may be placed under priority at any time. Finally, a third list is given of those materials which are considered questionable. Many of these items are manufactured from raw materials which are already on the priority or critical lists, therefore, these products should be investigated as to availability by each manufacturer who uses them.

Priority	*Critical*
Aluminum finishes	China wood oil varnishes
Zinc paints	Mineral paste fillers
Bronze, brass, or copper finishes	Natural resin fillers
	Shellac

Questionable

Synthetic varnishes	Metallic driers: manganese, zinc, lead, etc.,
Synthetic enamels	
Lacquer finishes	Inert pigment finishes
Lead paints	Natural wax finishes

Consult Sources of Supply

In conclusion, the committee recommends that manufacturers using any of these materials should consult their sources of supply in order to determine as accurately as possible the availability of such materials at the present time and in the near future. Also, it is recommended that association meetings of the users of finishing materials be held at early dates to consider specific substitutes for those items which are not likely to be available.

AT THE SPEAKERS' TABLE AT THE LOS ANGELES SECTION MEETING, MAY 15

(*Left to right:* Ray Roshong, membership chairman of the Section; L. L. Snyder, program chairman of the Section; Richard W. Palmer, vice-president, Vultee Aircraft, Inc.; Paul Armstrong, chairman of the Section; Ernest Bruce, chief engineer, Vultee Aircraft, Inc.; John D. Hackstaff, member of the executive committee of the Section.)

Los Angeles Breaks All A.S.M.E. Local Sections Attendance Records With 1500 at One Meeting

Ernest Bruce of Vultee Aircraft, Inc., Presents Design and Construction Analysis of Messerschmitt 110 Plane

THE largest audience ever to attend a single meeting of an A.S.M.E. Local Section, 1500 members and guests, was present at the May 15 meeting of the Los Angeles Section. At the last minute, the meeting had to be changed from its scheduled place in the Barker Brothers Building to the Elks Club because of the intense interest evinced in the session by Los Angeles engineers. The attraction was an analysis by Ernest Bruce, chief engineer of Vultee Aircraft, Inc., of a Messerschmitt 110 airplane recently presented by the R.A.F. to his company.

According to Mr. Bruce, the object of this gift was to enable local aircraft engineers to examine and analyze this modern German airplane for the benefit of the American aircraft industry. After outlining the construction and design of this plane, comparison was made with current American practice. The discussion was illustrated with motion pictures and detailed photographs of the Messerschmitt.

Anthracite-Lehigh Valley Meets in Hamburg in May

Twenty-seven were present at the dinner preceding the meeting and more than 50 at the May 23 meeting of the Anthracite-Lehigh Valley Section held in Hamburg, Pa. Dr. Harvey N. Davis, past-president A.S.M.E., and president of Stevens Institute of Technology, assisted by Tom Lasher, presented a paper on the subject of powder metallurgy. Many present commercial applications were mentioned and new ones were predicted. After a long discussion, the meeting adjourned to enable the members to examine the samples that had been prepared in the laboratories of Stevens.

Research Physicist Speaker at Central Pennsylvania

Dr. Saul Dushman, assistant director, General Electric Research Laboratories, taking as his topic, "A Physicist Looks at Metallurgy," addressed 92 members and guests of Central Pennsylvania Section at the May 27 meeting held in Altoona, Pa. The speaker explained how a physicist can solve many metallurgical problems through his knowledge of matter. He also discussed cohesion of materials and metallic creep.

Baltimore Engineers Hold Ladies Night

At the annual ladies' night meeting held on May 26 and attended by 50 members and 50 guests, the Baltimore Section presented Prof. David M. Robinson, who read a paper entitled, "Olynthus, a Greek Pompeii." He described his excavations and explorations in pursuit of the history and culture of ancient Greece. He showed slides of this work and revealed much of the life of these ancient people. Olynthus, not far from Athens, was destroyed by Philip centuries ago. Of interest was Professor Robinson's outline of numerous parallels in ancient and present-day happenings.

"Approved by the Underwriters" Subject of Bridgeport Meeting

On May 23 more than 125 members and guests of Bridgeport Section were present at Stamford in order to hear M. M. Brandon, associate electrical engineer, Underwriters Laboratories, Inc., talk on the subject of "Approved by the Underwriters." The paper was illustrated with motion pictures. Described and shown were fire tests of building materials, investigation of fire-fighting equipment, sprinkler systems, tests of electrical wiring and equipment, and check of efficiency of safes and burglar alarms.

Cleveland Ends 1940-1941 With Railroad Session

The 1940-1941 season of the Cleveland Section was concluded on May 15 with a meeting devoted to railroads. Through the efforts of D. S. Ellis and A. G. Trumbull excellent speakers were obtained. Fred Schmidt, mechanical engineer with the Baldwin Locomotive Works, delivered an illustrated paper on recent developments in steam locomotives. He was assisted by Paul Warner. Victor Willoughby, vice-president of the American Car and Foundry Company, traced the development of the modern railroad car from the earliest days of the American railroads up to the present time.

140 Attend Fuels-Lubricants Session of Colorado

More than 140 members and guests of Colorado Section attended the April 18 session at which A. F. Lyster, Socony Vacuum Co., read a paper illustrated with motion pictures on "Fuels and Lubricants for Gasoline and Diesel Engines." After discussing the theories of fuels and lubricants, he presented many problems and their solutions.

On May 9, Colorado Section featured a "Student Night Meeting" at which students from Colorado State College were the guests. R. W. Hammond described the different types and arrangements of slots and flaps used to assist airplanes in taking off and landing.

Detroit Features Paper on High-Temperature Steam

On May 6, Martin Frisch, chief engineer of the Foster-Wheeler Corporation, addressed

more than 100 members and guests of the Detroit Section, including several members of the Prime Movers Committee, on "Steam Temperature Control in High-Pressure, High-Temperature Steam Generators." Among the many methods of steam-temperature control having some practical application are: (1) By-pass damper, (2) saturated-steam condenser inside superheater inlet header, (3) heat exchange in superheater intermediate header, (4) boiler-drum steam coil, (5) external heat exchanger, (6) combination radiant and convection superheater, and (7) twin-furnace design. The first five types, however, lack many important and desirable features in regard to quickness of response to load changes, ability to compensate for slag formation, and a proper relation to economic considerations. The sixth type offers a reasonable compromise, providing boiler operation is under proper supervision. It has proved satisfactory in several cases.

The seventh type is a comparatively recent development. Steam generators of the twin-furnace type, in which superheated-steam temperature is controlled closely and accurately by the rate of coal firing in one of the combustion chambers, have given satisfactory service during the last two years. This design has been largely used by the U. S. Navy where reliability is deemed essential. The talk was well illustrated with slides showing technical information of practical value. A lively discussion followed the closure of the paper in which many points of interest to Detroit engineers were brought out.

Kingsport Scene of All-Day East Tennessee Meeting

An all-day meeting was held by East Tennessee Section in Kingsport on May 17. At the luncheon meeting, Roscoe W. Morton spoke on "Streamlined Trains." Following inspection trips, informal discussion groups, and golf in the afternoon, the members gathered for a sumptuous dinner. The evening was concluded with a talk on "Defense Contract Service," by W. C. Cram, Jr., Defense Contract Service of the O.P.M., and a round-table discussion on the National Defense Program led by J. P. Ferris.

Hold Senior-Junior-Student Meeting at Kansas City

A senior-junior-student meeting sponsored by the Kansas City Section and participated in by the Junior Group, University of Kansas Student Branch, and Kansas State College Student Branch was held on April 17. Prize-winning papers were presented by Harry Orth, Junior Group, Robert G. Hampell, University of Kansas, and Phillip Myers, Kansas State College.

Mid-Continent Hears G. O. Kimmell on Distillate-Well Evaluation

Approximately one hundred people attended the meeting of the Mid-Continent Section on April 14 to hear an address by Garmon O. Kimmell of the firm of Black, Sivall & Bryson who gave a talk on test procedure for evaluating distillate wells. Mr. Kimmell illustrated his paper with slides and moving pictures showing the apparatus he uses and the method of taking samples, making the test run, and evaluating the data. Lively discussion followed the paper's presentation which was thoroughly enjoyed by an interested audience.

Talk on Plastics and Machine Tools Before Milwaukee Section

Dr. H. A. Frommelt was the guest speaker at the May 14 meeting of the Milwaukee Section. He gave a talk, illustrated with samples and colored motion pictures, on plastics and machine tools.

President Hanley of A.S.M.E. Welcomed in New Orleans

William A. Hanley, president of A.S.M.E., was the guest of honor at a dinner of the New Orleans Section held on May 12. Following his introduction by James M. Todd, Mr. Hanley gave a brief talk relative to A.S.M.E. activities and national defense. This was followed by a joint meeting with the Louisiana Engineering Society in the St. Charles Hotel. The chairman, Dr. L. J. Lassalle, introduced Laurance S. Reid, University of Oklahoma, who delivered a comprehensive discussion, illustrated with slides, of "The Need for Further Development in Gas Cycling and Condensate Recovery." The paper covered the various techniques employed in present practice and demonstrated the necessity for further expansion and development. Dr. Lassalle then introduced President Hanley, who presented an address entitled, "Why National Defense—An Engineer's Viewpoint." This proved to be a timely and popular subject and was received with keen interest by the entire audience.

Students Given Awards by Raleigh Section

At the final meeting of 1940-1941 on May 22, Raleigh Section awarded to Fred R. Ervin, Duke University Student Branch, and J. S. Avent, North Carolina State College Student Branch, copies of a mechanical-engineering handbook for outstanding service to their respective student organizations. Wives of the members of the Section were guests at dinner preceding the meeting which was held at the Duke University Men's Union. Entertainment of a light and magical nature was presented by "Wallace the Magician."

Susquehanna Section Is Host to President Hanley

The meeting of the Susquehanna Section on April 23 was devoted to "National Defense" in honor of William A. Hanley, President of the A.S.M.E., who was the guest speaker. In his paper, President Hanley outlined the many opportunities available to engineers to help their country in this national emergency.

San Francisco Section Holds Production Meeting

"Bursting the Bottleneck in Production," was the subject of the joint senior-junior session held on May 22 by the San Francisco Section. In this symposium on production methods applicable to defense industries, Walter Kassebohm, plant manager of the Autometric Machine Tool Co., described the manufacture and use of machine tools, and Harold T. Avery, chief engineer, Marchant Calculating Machine

NEWLY ELECTED OFFICERS OF THE A.S.M.E. WEST VIRGINIA SECTION, 1941–1942

(*Standing, left to right:* Henry C. Lewis, J. Gilbert Miller, J. Laurance Barker, Jr., C. B. Cochran. *Seated, left to right:* Marvin S. Bloomsburg, Arthur H. Cannon. Not present when picture was taken: Geo. J. Huber, Jr., and Minott Brooke.)

Co., and new chairman of the Section, discussed "Dimensional Control in the Manufacture of Small Machine Parts." One of the interesting points brought out was the fact that five men were used in production for every man on the battle front in 1914–1918, while today 18 men are required for every soldier.

Waterbury Is Host to Other Connecticut Sections

Waterbury Section was host on May 17 to New Haven, Watertown, Bridgeport, Hartford, New Haven, and Norwich Sections of the A.S.M.E. for their tenth annual affair. Because of the restrictions under the National Defense Program, the usual plant visitations were omitted. Instead, golf, tennis, an exhibit of early American glass, and a get-acquainted hour were the afternoon attractions. Following dinner, two interesting speakers were presented. Prof. Lauren E. Seeley, Yale University, in his paper, "Training for Defense," discussed the intensive training given to those who are desirous of increasing their usefulness to defense industries and how they are being prepared to assume increased responsibilities. Dr. Harvey N. Davis, president of Stevens Institute of Technology, talked on "Priorities in Men."

More Than 100 Engineers at West Virginia Meeting

At the April 28 meeting of the West Virginia Section, more than 100 members and guests learned about "Flowmeters" from R. A. Weikel, Brown Instrument Company. He gave the history of measuring devices, touched on the theory behind their operation, and explained the relative worth of the four primary devices and the superiority of the thin-plate orifice because of its simplicity of manufacture, installation, and replacement.

A photograph of the newly elected officers of the West Virginia Section appears on page 565 of this issue.

Los Angeles Juniors Have Papers by Juniors and Students

More than 100 members and guests were present at the April 17 meeting of the Los Angeles Junior Group. Five papers were presented by Juniors, including Bernard Tobin, "Machine Accounting for Production Control," A. Alter, "Production in Pipe-Line Installation," R. Aaron, "Spot Welding of Thin-Skin Structures," J. Spievak, "Riveting of Aircraft Structures," and F. Carlisle, "Metallographic Methods in Production."

On May 1 the Junior Group sponsored a meeting at which papers were presented by A.S.M.E. student members from the University of Southern California and California Institute of Technology. Speakers included George Sutton, Wilton Stewart, Don Campbell, Frank Scott, Scott Salisbury, and Robert Hoffman. First prize of $25 went to Campbell for his paper on "Impact Testing," and the second prize of $10 was awarded to Hoffman for his talk on "A Concrete Fatigue Tester."

Department of Commerce Sets Up Service and Information Office

APPROXIMATELY 2500 government purchasing agencies purchase some 300,000 different articles. Indeed, the government buys some quantities of almost everything produced in this country.

The magnitude of the government purchasing setup, especially in this grave emergency when first emphasis is necessarily placed upon defense equipment for the expanding Army and Navy and for Great Britain, tends to confuse many manufacturers who desire to cooperate 100 per cent.

Actually, government purchases are made on a very simple formula. The specifications are not complicated. In fact, the biggest buyer in the world—Uncle Sam—has the simplest system of purchasing supplies, equipment, and services. The system functions something like a large mail-order house, except that where the latter sells to thousands, the government buys from thousands.

Selling to the Government

How can a businessman sell to the government?

The initial venture of selling to the government will, of course, present some new problems. None of these problems, however, are necessarily complicated. In order to help manufacturers solve them, Jesse Jones, Secretary of Commerce, early in his administration set up a Service and Information Office, staffed with men who have had years of service in government and have recently completed months of intensive study of the purchase systems of each governmental office.

Consequently, the Service and Information Office is equipped to inform manufacturers whom they should contact and exactly how to do so. A manufacturer who desires to cooperate with the government in the present emergency, and lacks specific information as to how to proceed, is invited to apply to this unit, Room 1060, Department of Commerce, Washington, D. C. The effectiveness of the assistance rendered by the Office is demonstrated by the large number of telegrams and letters of appreciation which it has received.

Many manufacturers apparently have felt that if they desire to transact business with the government they must either go to Washington in person or employ somebody familiar with government purchasing methods.

Don't Go to Washington—Write

The Service and Information Office strongly urges manufacturers not to go to Washington, at least not until they have carried on preliminary negotiations by mail with the purchasing agency that handles their particular products.

They are advised not to employ outsiders on a commission or other basis. In fact, the War and Navy Departments and the Office of Production Management have repeatedly warned against the employment of what are termed "lobbyists" in the effort to obtain government contracts.

Furthermore, the Army, for example, has decentralized its purchasing system. Different depots specialize in purchasing specific supplies. Clothing is purchased in Philadelphia; shoes in Boston; various kinds of equipment in Jeffersonville, Ind.; aircraft supplies in Dayton, Ohio. A very small percentage of Army supplies is purchased in Washington.

The Navy too has part of its purchasing system decentralized and prefers to have preliminary negotiations conducted by mail. The Bureau of Supplies and Accounts purchases a major proportion of Navy supplies, aside from contracting for ships.

A third large purchasing agency of the government is the Procurement Office of the Treasury Department, a centralized purchasing agency for all departments except the Army and Navy. The Procurement Office has also branches in different parts of the country and prefers that preliminary negotiations be conducted by mail.

When it is necessary to go to Washington, the Service and Information Office will gladly arrange for the businessman to see the particular official with whom contact should be made.

New A.S.M.E. Membership List Scheduled for 1942

AN up-to-date directory of A.S.M.E. members is to be published in February, 1942, replacing the issue of February, 1940. Combined with the annual issue of the Society Records devoted to Council and committee personnel and other information of general interest, and also the revised Constitution and By-Laws of the Society and the Professional Service Index, the new directory will form Section Two of the regular February issue of Transactions.

The directory will include the names of all members in good standing (i.e., dues paid in full for the fiscal year ending September 30, 1941). It will be distributed to all members who are entitled to the publications of the Society at the time of mailing.

In the early fall members will be given an opportunity to indicate how they desire to be listed in the directory, and if they are to be included in the Professional Service Index.

Bibliography on Induction Heat-Treatment

THE Engineering Societies Library has prepared a list of selected references on the heat-treatment of metals by induction heating. Forty papers of importance are listed, selected from domestic and foreign periodicals, dealing with the metallurgical problems involved, the design of heating coils and electrical circuits, and with typical actual installations.

Members of the Founder Societies may obtain copies by sending $1 to the Engineering Societies Library, 29 West 39th Street, New York, N. Y. The price to others is $1.25.

(*A.S.M.E. News continued on page 568*)

SPECIFY Tube-Turns FOR EVERY WELDING FITTING NEED!
Available in all sizes in Standard, Extra Heavy, Double Extra Heavy and Special Thicknesses. Write for catalog and data book.
45° ELBOW
90° ELBOW
180° RETURN
TEE
ECCENTRIC REDUCER
CONCENTRIC REDUCER
SADDLE
NIPPLE
LATERAL
CAP
WELDING RING
SLIP-ON FLANGE
WELDING NECK FLANGE
The FIRST WELDING FITTINGS 1ST AND STILL THE BEST
TUBE-TURN Welding Fittings
TUBE-TURNS, Inc. Louisville, Ky. • Branches: New York, Chicago, Philadelphia, Pittsburgh, Cleveland, Los Angeles. Distributors Everywhere.

A.S.M.E. Calendar

of Coming Meetings

October 12–15, 1941
Fall Meeting
Louisville, Ky.

October 30–31, 1941
Joint Meeting of A.S.M.E. Fuels and A.I.M.E. Coal Divisions
Lafayette College
Easton, Pa.

December 1–5, 1941
Annual Meeting
New York,
N. Y.

(For coming meetings of other organizations see page 22 of the advertising section of this issue)

Government Seeks Mineral Economists

THE Government is looking for persons especially qualified in the economic aspects of the mineral industries to do professional research in the fields of minerals, coal, and petroleum. Civil-service examinations for these positions are now open. The salaries range from $2600 to $5600 a year. Applications will be rated as received at the Commission's Washington Office but interested persons are urged to file applications at once.

Further information, including the exact education, experience, and substitution provisions, is contained in the formal announcement. Announcements and application forms may be obtained from any first- or second-class post office or from the Civil Service Commission, Washington, D. C.

Navy Needs More Inspectors of Ship Construction and Engineering Materials

AN effort is being made by the U. S. Civil Service Commission to meet the demand for inspectors of ship construction and engineering materials in the Navy Department. New examinations for these positions, with modified requirements, have just been announced. Announcement No. 81 for inspector of engineering materials and announcement No. 82 for inspector of ship construction cancel and supersede Announcement No. 103 of 1940, the original announcement of the examinations for these positions. Persons qualified under the new examinations are urged to file application at once, although applications will be accepted until further notice.

The formal announcements give the complete requirements, including the specific types of substitutions that may be made for the inspectional experience. Persons who are interested are urged to apply for further information and application forms to any first- or second-class post office, or to the Civil Service Commission in Washington, D. C.

Men and Positions Available

Send Inquiries to New York Office of Engineering Societies Personnel Service, Inc.

29 W. 39th St., New York, N. Y. | 211 West Wacker Drive, Chicago, Ill. | 57 Post Street, San Francisco, Calif. | Hotel Statler, Detroit, Mich.

MEN AVAILABLE[1]

PLANT ENGINEER, 51, married; employed in East. Broad experience in directing plant maintenance, construction, and power-plant operation. Chemical and general manufacturing experience. Good personality. Executive ability. Me-653.

MECHANICAL ENGINEER, 37; 13 years thermodynamical, mechanical design, stress analysis, on steam turbines; 6 years design machine tools. Wishes permanent connection in field of heavy machinery. Middle West preferred. Me-654.

EXECUTIVE, 42; M.E. Experienced in management of business of around 100 employees; 12 years of aluminum and brass foundry operation and allied manufacturing. Complete cost, production, and planning control. Now employed. Me-655.

PROFESSOR, 45, married. Experienced in heat engineering, mechanics, machine design. Doctor of science, M.I.T.; 11 years' teaching experience. Now employed as machine designer. Location, U.S.A. Available two weeks notice. Me-656.

EXECUTIVE AND INDUSTRIAL ENGINEER, graduate Cornell University, E.E. Fifteen years management and professional experience. Installed and operated successfully cost-accounting and production-control systems. Qualified in personnel, maintenance, purchasing, waste-elimination, wage and key-man incentive programs. Me-657.

RECENT GRADUATE MECHANICAL ENGINEER, 21, B.M.E., 1941. Upper eighth of class, editor of college technical magazine. Desires position offering training for production planning and supervision, management, design, or research. Creative ability. Me-658.

MECHANICAL ENGINEER, 24, 1939. Experienced in commercial refrigeration and radio servicing, can merchandise and make factory service reports. Available now. Desires position in factory production or sales engineering. Me-659.

GENERAL ENGINEER wants position on plant labor improvement, job training, and orientation classes. Temporary position. Favorable results. Me-660.

MECHANICAL ENGINEER, 29; married. P.E., N. Y. State. Eight years' field and design experience steam power-plant equipment. Interested in engineering openings in Latin America. Fluent Spanish. Now employed. Me-661.

MECHANICAL ENGINEER, June, 1941; 21. Summer experience factory design, production. Special training aeronautical stress analysis. Desires position with substantial firm, preferably near New York. Field with future and interest. Me-662.

GRADUATE MECHANICAL ENGINEER, 27. Desires change to responsible industrial or consulting position; New England preferred. Experience includes textile, Southern pulp and paper industry, industrial control instrumentation. Me-663.

[1] All men listed hold some form of A.S.M.E. membership.

POSITIONS AVAILABLE

ELECTRICAL ENGINEER, preferably under 30, for traction power production and distribution (also catenary), including design, construction, drafting, supervision. Preferably not within present or prospective draft or other military service. Salary, $2400 year to start. New England. Y-7974.

INSTRUCTOR in mechanical engineering, preferably graduate of recognized university. Practical work more desirable than teaching experience. Will have charge of mechanical laboratory and will handle some classroom work in heat engines and thermodynamics. Salary about $2400 for school year. Location, South. Y-8203.

MATERIALS-HANDLING ENGINEER, mechanical or industrial, for special studies and preliminary design on conveyer problems for large, light-material manufacturing company. Salary, $5000–$6000 year. South. Y-8210.

MECHANICAL ENGINEER having experience with pulverized-fuel-firing equipment, to act as field superintendent and service engineer, installing, operating, and testing such equipment. Apply by letter stating experience, references, salary expected. Location, Middle West. Y-8221-C.

GRADUATE MECHANICAL OR CHEMICAL ENGINEER, 25–30, with several years of plant-engineering or maintenance experience in chemical plant. Salary open. Pennsylvania. Y-8225.

PLANT MANAGER thoroughly familiar with process of casting aluminum. Will be responsible for management of new plant. Good opportunity. Salary, $5000–$6000 a year, plus bonus. Pennsylvania. Y-8242.

DESIGNER of oil-well drilling tools involving actual design, development, and testing of oil-well drilling cutters, of cone and roller type for rotary drilling rigs. Will also work on associated equipment. Oil-field experience unnecessary but would be advantageous. Should be experienced in metallurgy and in design of roller and ball bearings and have fair knowledge of mathematics. Salary open. Location, East. Y-8253.

ASSISTANT PROFESSOR to teaching the following: direct-current machinery, alternating-current machinery laboratory, electronics laboratory, thesis conference, alternating-current-circuits laboratory, communications engineering (lecture and laboratory), engineering report writing (lecture). Eleven clock hours per week, first semester; thirteen clock hours per week, second semester. Salary,

(A.S.M.E. News continued on page 570)

NOW—FOR THE FIRST TIME

Low-price Direct-current Recorders

Obtaining a permanent record of a tube plate current with a CF-2 d-c milliammeter

for
Low-range and
High-sensitivity
Measurements

Milliammeters
Microammeters
Millivoltmeters
and
Ammeters
Voltmeters

THIS new line of instruments (Type CF-2) makes it possible to obtain permanent records of circuit conditions where, previously, only indicating instruments, or expensive recording equipment, were available.

You will find these instruments ideal for electronics work because of their low power consumption.

THEY'RE INKLESS

There's no ink to spill, blur, or freeze. You are sure to obtain accurate records in temperatures from —10F to 120F, and rapidly fluctuating loads will not cause "painted" charts.

The CF-2 recorder is small, sturdy, accurate within 2 per cent, and readily portable—it weighs only 12 pounds. A reliable Telechron motor feeds the chart at either 1, 2, or 3 inches per hour.

For a-c measurements, the companion Type CF-1 instrument is available.

Get complete information from the nearest G-E Office. Ask for our Bulletin GEA-3187, General Electric, Schenectady, N. Y.

APPLICATIONS

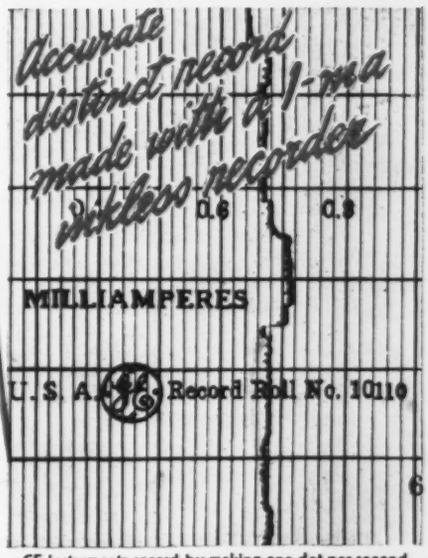
Here are just a few of the many possible uses for these recorders:

1 Development work—permanent records of circuit conditions will minimize the need for cut-and-try work, and will facilitate the duplication of test set-ups.

2 Smoke density—a recorder, used with auxiliary equipment, is an inexpensive way to obtain permanent records of smoke density, so that you will have proof for city inspectors.

3 Vacuum-tube circuits—to record plate current or voltage.

4 Moving vehicles—to study battery and generator performance.



CF instruments record by making one dot per second. This record was made with a relatively constant current. On fluctuating circuits the record may not be continuous, but the density of the dots gives an indication of the average current or voltage.

TYPICAL CHARACTERISTICS OF A POPULAR RATING

Range	0 to 1 ma
Resistance	16 ohms, approx.
Response time	3 sec. approx.
Dimensions	8 9/16 by 10 9/16 by 5 31/32 in.
Scale length	3 1/2 in.
Chart speed	3 in. per hour

GENERAL ELECTRIC

602-18